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VARIATIONS IN THE URANIUM AND RADIOACTIVITY LEVELS OF POTABLE SURFACE AND GROUND WATER IN THE OKANAGAN AND WEST KOOTENAY REGIONS OF BRITISH COLUMBIA

Published by authority of:

THE HONOURABLE ROBERT MCCLELLAND

Minister of Energy, Mines and Petroleum Resources

and

THE HONOURABLE RAFE MAIR

Minister of Health

Victoria, British Columbia
April 1980

Province of
British Columbia

Ministry of
Energy, Mines and
Petroleum Resources

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Acknowledgements

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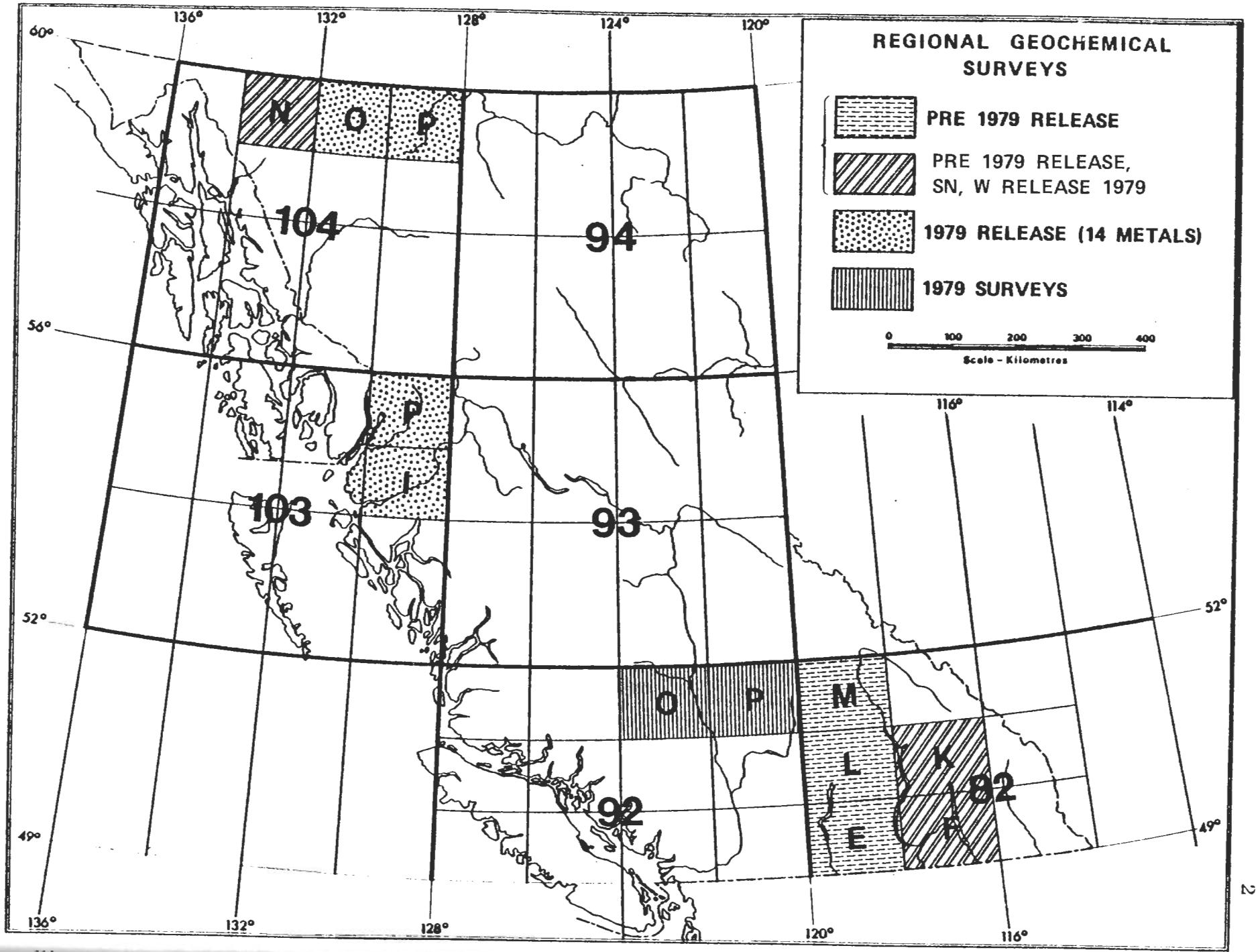
INTRODUCTION

The earth's crust contains many naturally occurring elements which are radioactive. Examples of such elements are radium, thorium and uranium. The presence and the chemical occurrance of such elements vary widely and may be in a form where they may be mobilized within the environment by climatic changes, weathering or by man's activities. All living organisms, including man, are sensitive to radiation exposure. Certain elements are more hazardous than others (in terms of radioactivity) and therefore their presence in the environment must be monitored, especially in regards to public health considerations.

Guidelines for Canadian drinking water quality have been developed for certain radioactive elements which are found in the environment (Health and Welfare Canada 1979). Among these elements are radium 226 and uranium (uranyl ion). The recommended guideline or maximum acceptable concentrations (MAC) are 1.0 Bq/l* for radium 226 and 0.02 mg/l (20 ppb) for uranium.

Initial information on background uranium concentrations in British Columbia streams was obtained from Uranium Reconnaissance Program geochemical maps produced jointly by the Geological Survey of Canada and the B.C. Ministry of Energy, Mines and Petroleum Resources (1976 and 1977) as part of a joint Federal/Provincial cost sharing program. This program was extended by the B.C. Ministry of Energy, Mines and Petroleum Resources and covers the 1978 and 1979 survey areas shown on Figure 1 (Sutherland Brown, A., et al., 1979). In several areas the measured total uranium concentrations approached the recommended MAC value. Some of these water systems supplied drinking water to local residences and should be sensitive to environmental changes and thus result in values above the maximum acceptable concentrations.

*1 Bequerel (Bq) = 1 disintegration per second
1 pCi = 37 mBq


REGIONAL GEOCHEMICAL SURVEYS
PRE 1979 RELEASE
PRE 1979 RELEASE, SN, W RELEASE 1979
1979 RELEASE (14 METALS)
1979 SURVEYS
0 100 200 300 400
Scale - Kilometres
104
94
103
93
92
82
N
O
P
I
M
L
K
E
F
60°
56°
52°
49°
136°
132°
128°
124°
120°
116°
114°

The Uranium Reconnaissance Program maps are based on the results of only one sampling and therefore, their reliability for interpretation of public health considerations is limited. For example, Kleiber, et al. (1978) have shown that nutrient concentrations in the Okanagan River exhibit considerable seasonal variation and concluded that a single measurement could result in an erroneous interpretation.

The Ministry of Health and the Ministry of Energy, Mines and Petroleum Resources recognized the limitations of the URP data and the interpretation of such data and decided to examine temporal and geographic variations of uranium and radioactivity levels in potable water within selected areas of south central British Columbia. An outline of the study which was to be carried out is presented in Appendix 1. The funding for the analysis, performed by Chemex Labs Ltd., was obtained from the Ministry of Energy, Mines and Petroleum Resources. The sample collection was done by Ministry of Health field personnel.

The purpose of this study is to investigate temporal and geographic variations in uranium, gross alpha and beta activity levels in potable surface and ground waters in (i) catchments where-in NGR Program maps indicated enhanced uranium concentrations and (ii) around sites of possible uranium mining activity, i.e. known uranium deposits.

To this end five separate study areas were chosen in the Okanagan and West Kootenay regions of south-central British Columbia (Fig.2). Two of these, Summerland and Nelson Areas, include reportedly uranium-enriched streams. Potentially economic uranium mineralization occurs in both

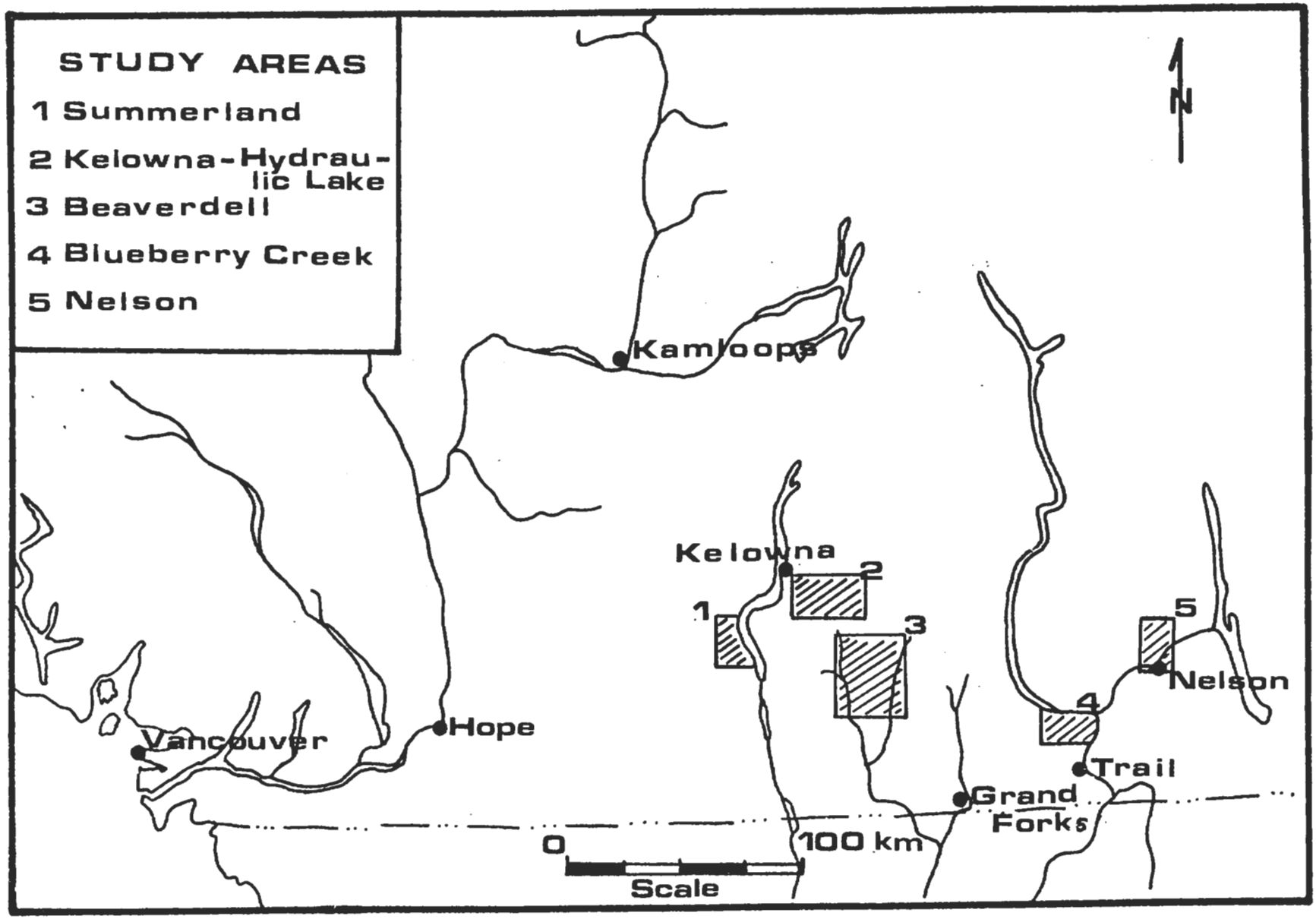


FIGURE 2. Location of study areas.

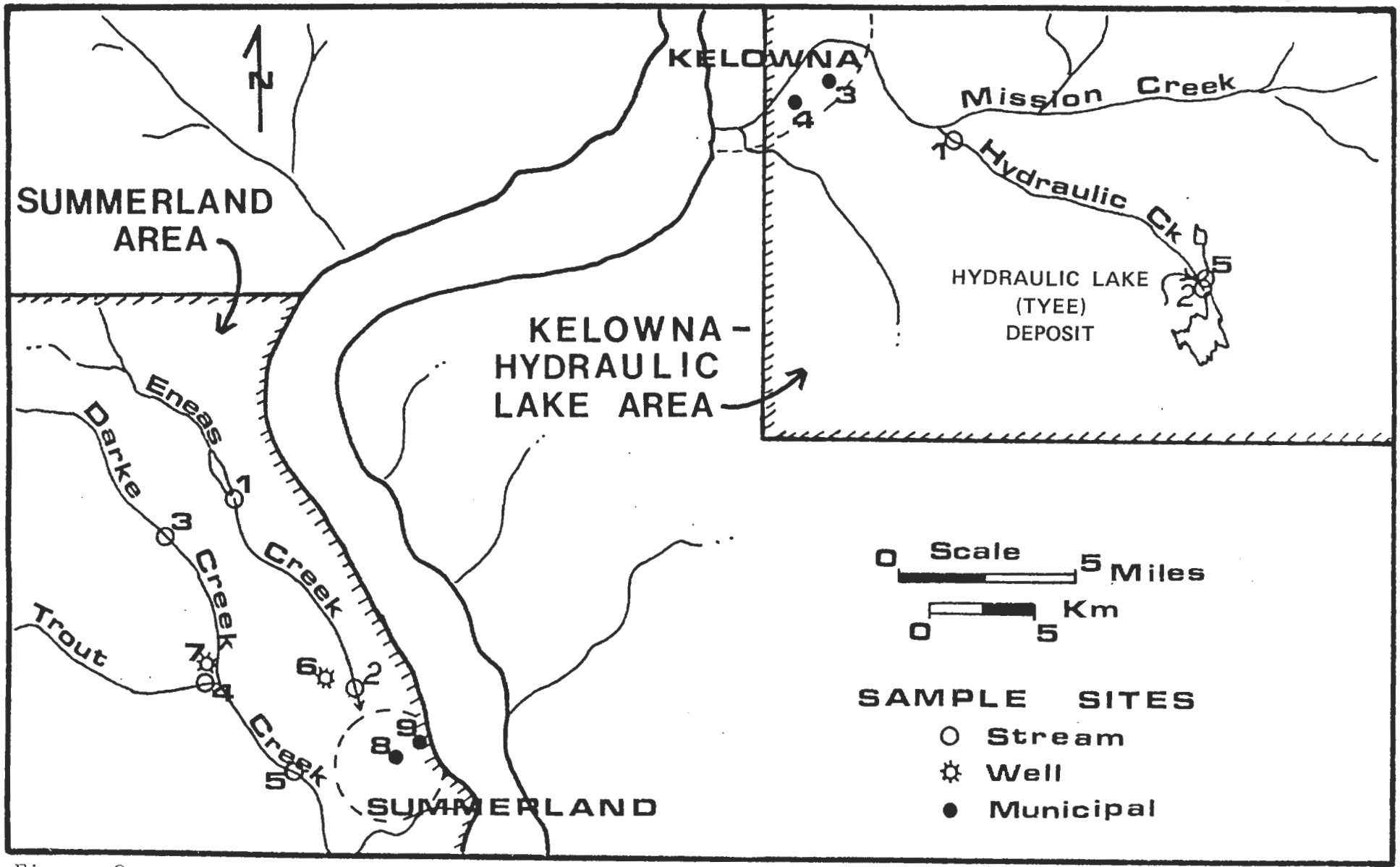

N
KELOWNA
Mission Creek
Hydraulic Ck
SUMMERLAND AREA
HYDRAULIC LAKE (TYEE) DEPOSIT
KELOWNA - HYDRAULIC LAKE AREA
Eneas Creek
Darke Creek
Trout Creek
SUMMERLAND
Scale
0 5 Miles
0 5 Km
SAMPLE SITES
Stream
Well
Municipal

Figure 3

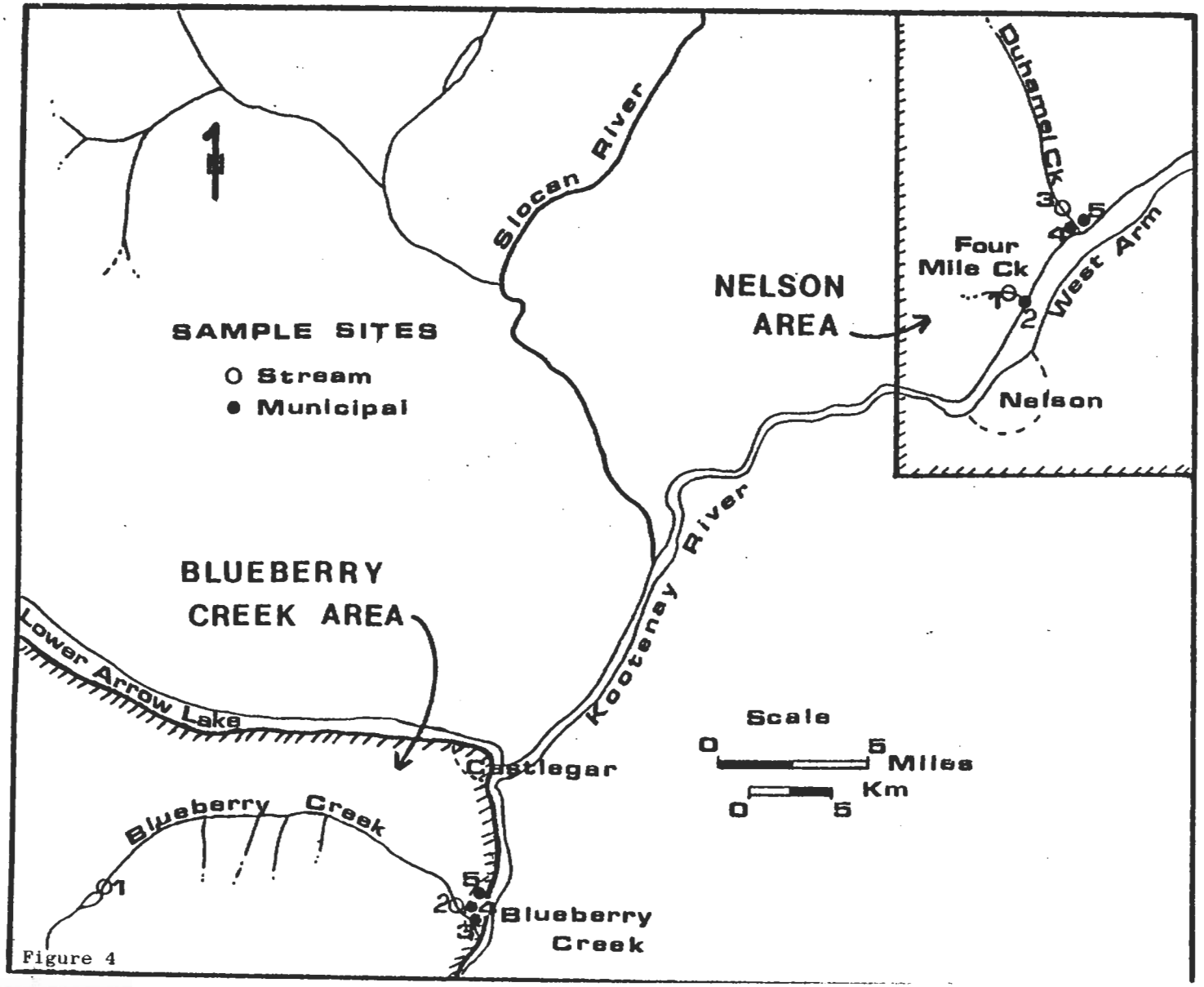

SAMPLE SITES
O Stream
● Municipal
Slocan River
Duhamel Ck
Four Mile Ck
West Arm
NELSON AREA
Nelson
Kootenay River
BLUEBERRY CREEK AREA
Lower Arrow Lake
Castlegar
Blueberry Creek
Blueberry Creek
Scale
0 5 Miles
0 5 Km

Figure 4

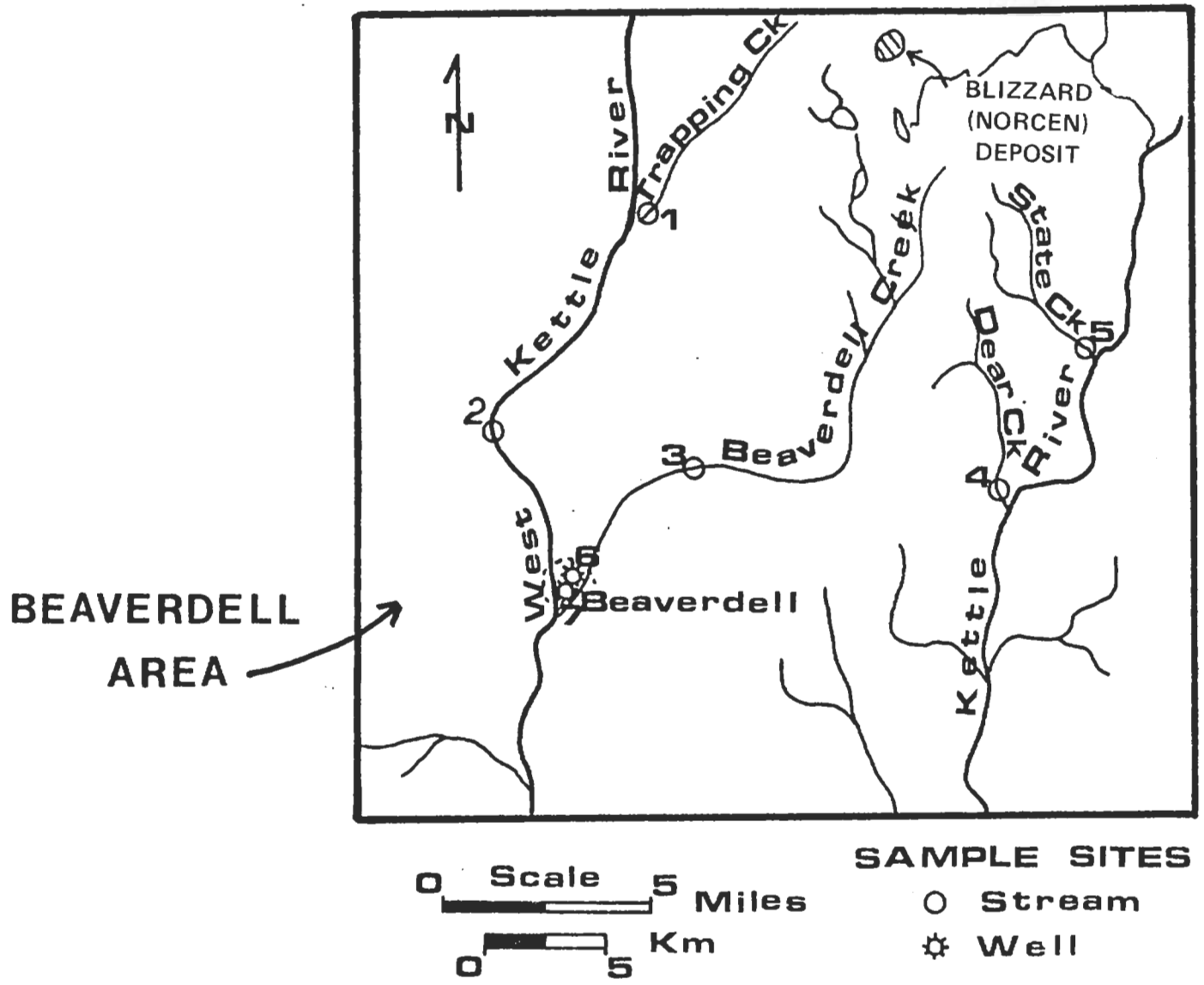

BEAVERDELL
AREA
N
Kettle River
Trapping Ck
BLIZZARD
(NORCEN)
DEPOSIT
State Ck
Beaverdell Creek
Bear Ck
River
West
Beaverdell
Kettle
1
2
3
4
5
6
7
0 Scale 5 Miles
0 5 Km
SAMPLE SITES
Stream
Well

Figure 5

TABLE 1

SAMPLE SITES

AREA	SITE
(1) Summerland (SU)	
	(1) Garnet Lake Spillway (Eneas Creek)
	(2) Eneas Creek near Summerland
	(3) Darke Creek above Trout Creek
	(4) Trout Creek at Junction of Darke and Trout Creek
	(5) Trout Creek at Municipal Water Intake
	(6) Well near Eneas Creek
	(7) Well near Darke Creek
	(8) South Okanagan Health Unit office (municipal supply)
	+(9) Summerland home (municipal supply)
(2) Kelowna-Hydraulic Lake (KL)	
	(1) Hydraulic Creek at Municipal Intake
	(2) Hydraulic Lake at Spillway
	(3) South East Kelowna Irrigation Distric Office (municipal supply)
	+(4) Kelowna home (municipal supply)
	+(5) Fish Creek
(3) Beaverdell (BR)	
	(1) Trapping Creek
	+(2) West Kettle River
	(3) Beaverdell Creek
	(4) Dear Creek
	(5) State Creek
	(6) Beaverdell Forestry Office (municipal well)
	+(8) Beaverdell home (municipal well)
(4) Blueberry Creek (BC)	
	(1) Blueberry Creek at Lake
	(2) Blueberry Creek at Municipal Intake
	+(3) Blueberry Creek Home (municipal supply)
	(4) Blueberry Creek Home (municipal supply)
	+(5) Blueberry Creek Home (municipal supply)
(5) Nelson (NL)	
	+(1) Four Mile Creek
	(2) Four Mile Creek Home (Tap Water)
	+(3) Duhamel Creek
	(4) MacDonald Landing School (Tap Water)
	+(5) MacDonald Landing Home (Tap Water)

+ Sites not analysed by Chemex after May, 1979.

the Kelowna-Hydraulic Lake* and Beaverdell areas. The Blueberry Creek area was selected for control purposes. Table I lists the specific sample sites for each area including a brief description. Fig. 3, 4, and 5 show site locations.

Examination of the Feb. - May data indicated that adequate coverage could be maintained with as few as 20 of the original 31 sample sites. Thus beginning in June the number of sites routinely monitored by Chemex was reduced accordingly (as shown in Table 1). Monthly samples from the remaining 11 sites are being analysed for radium and uranium at the B.C. Government's Environmental Laboratory.

* This area is also referred to simply as the Kelowna or Hydraulic Lake areas in this report.

II METHODS

SAMPLE COLLECTION AND TREATMENT

Grab samples were collected at one month intervals at each of 31 sites distributed among the five areas of study. In addition composite samples were collected periodically from selected tap water sites. Sampling began in February, 1979 and was continued until January, 1980. Samples were collected by local Medical Public Health Inspectors. Names and addresses of individuals involved are given in Appendix II.

When obtaining tap samples, water was allowed to flow for several minutes prior to collection to minimize chances of contamination from pipes or plumbing fixtures. All samples were collected in either new or acid-washed plastic containers. For the regular monthly samples two containers of 250 mL and one litre capacities were used. The one litre sample, for gross alpha and beta measurements, was acidified with 5 mL of concentrated nitric acid. The 250 mL sample was untreated, and used for the determination of uranium, conductivity and pH. Hall (1979) investigated the stability of uranium in surface waters from various parts of Canada and concluded that in general preservatives need not be added.

Composite samples were collected at a limited number of tap water sites over either monthly or weekly intervals. Both 4 litre and one litre size plastic containers were used for the monthly composites. Fifty to one hundred mL were added per day to the 4 litre bottles, and 25 mL to the one litre bottles. Concentrated nitric acid (10 mL) was added to the larger container which was used for radioactivity

measurement. The smaller unpreserved sample is taken for the determination of uranium, conductivity and pH. In the case of the weekly composites 25 mL of water was added daily to a 250 mL bottle and only uranium, conductivity and pH are measured.

All samples are shipped by courier to Chemex as soon as possible after collection.

ANALYSIS

Uranium

Unless otherwise stated all samples for uranium analysis were unpreserved and unfiltered.

Samples collected during the first three months of the project (February - April) were analysed by a direct fluorometric procedure similar to that described by Smith and Lynch (1969). Beginning in May, however, this method was modified to incorporate a MIBK-TPAN extraction (American Society of Testing Materials, 1975) in order to minimize possible matrix induced fluorescence quenching.

(i) Direct method: A 50.0 mL aliquot of water is treated with nitric acid and evaporated to dryness. The sample is then ashed and the residue taken up in nitric acid. A 0.200 mL subsample of this solution is micro-pipetted into a platinum dish and evaporated to dryness. Sodium carbonate/potassium carbonate/ sodium fluoride flux is added to the dish and the mixture fused. After cooling, fluorescence of the fused tablet is measured on a Turner Model 111 fluorometer and compared to standard solutions carried through the same procedure.

(ii) Extraction method: This procedure differs from the direct method in that water is treated with perchloric acid prior to initial evaporation to dryness. The residue is taken up in perchloric acid and a small volume of solution transferred to a test tube for extraction of uranium with TPAN (tetrapropylammonium nitrate) in MIBK (methyl isobutyl ketone). An aliquot of the organic layer is micro-pipetted into a platinum dish. Subsequent flux addition, fusion and fluorescence measurement steps are identical to those for the direct method.

The two procedures are deemed to be equivalent with the exception of the extraction procedure. This step is used to perferentially remove uranium from the water sample and deposit it into a more uniform noninterfering medium. Extraction efficiencies were shown to be near unity for uranium values above 1 ppb. Below 1 ppb realisitic efficiencies could not be determined due to the relatively high analytical errors involved.

Both methods give a detection limit of 0.05 ppb U. The precision is expected to be in the range:

	0.05 - 0.25	± 50%
	0.26 - 0.50	± 20%
and	>0.5	± 10%

GROSS ALPHA, BETA ACTIVITY

Gross alpha and gross beta activity measurements have been performed using a Canberra Model 2200 Low Level Alpha Beta Analyzer especially designed for environmental samples. This instrument consists of an

external proportional counter with an ultrathin Mylar window; the counter is completely surrounded by four inches of virgin lead and requires ultrahigh purity P-10 counting gas (90% argon - 10% methane). The instrument was calibrated with alpha activity by standardizing with an Americium-241 source (New England Nuclear Ltd.) which was previously calibrated against U.S. National Bureau of Standards Americium-241 alpha disc. It had a total uncertainty of not greater than $\pm$ 4.8% in its activity. The instrument was calibrated for beta activity by standardizing with a Cs-137 source (New England Nuclear Ltd.) which had also been previously calibrated against a U.S. National Bureau of Standards gamma source. It had a total uncertainty of not greater than $\pm$ 4.2% in its activity.

In order to compensate for self-absorption effects in the counting planchets, alpha and beta standards were prepared in a series of varying solids thickness. For these efficiency curves, the alpha standard was used for natural uranium and the beta standard used was Cs-137. The solids mixture consisted primarily of a mixture of organic compounds (sugar and acids) spiked with calcium and magnesium.

Procedure:

A 200 mL aliquot of homogenized acid - preserved sample was evaporated to a few millilitres in Teflon beakers. The residual material was transferred to a tared counting planchet and the final evaporation was completed under an infrared lamp to ensure uniform deposition. Samples were then dried in an oven at 105°C for one hour, cooled in a desiccator, weighed and counted

for 100 minutes. Two background counts of fifty minutes each were performed every day and all detectors were checked daily using Am-241 and Cs-137 sources. Detection limits of 40 mBq/L for gross alpha activity and 100 mBq/L for gross beta activity were routinely obtained with this method. Where measurable activities are reported, the uncertainty associated with the measurement is reported at the 95% (2 sigma) confidence level. This uncertainty is strictly intended to show that the result is a statistically significant count. It does not take into account any analytical or sampling variability. This procedure was adapted from APHA 'Standard Methods' 14th ed. 1975 pp. 648-653.

RADIUM - 226

This parameter was measured on a small number of samples of high gross α (>300 mBq/L) and a Gross α : U conc. ratio >10.

Radium-226 measurements were performed using a Canberra Model 2200 Alpha Beta Analyzer, described previously. A certified Ra-226 standard (Amersham Radiochemicals) which had been previously calibrated against a U.S. National Bureau of Standards Ra-226 source had a total uncertainty of not greater than $\pm$ 3.9% in its activity.

Radium-226 was determined by the precipitation method in which radium is isolated by a radiochemical separation involving coprecipitation with barium sulfate. The radium barium sulfate precipitate is stored for a week to allow for the ingrowth of radon and its daughters, thereby increasing the sensitivity of the method. The precipitate is then alpha-counted and compared with standards carried through the same procedure.

Procedure:

Samples for total Ra-226 were acidified to 1% HNO_3 at the time of collection and subsequently digested with perchloric acid. Samples for dissolved Ra-226 were filtered through a 3.0 micron membrane filter and then acidified to 1% HNO_3. Following digestion or filtration, radium is removed from solution by coprecipitation with lead sulfate. The lead sulfate is then dissolved in alkaline ethylene-diaminetetraacetic acid, barium carrier is added and barium sulfate preferentially precipitated by lowering the pH to 4.5. Radium is coprecipitated with the barium sulfate, redissolved and reprecipitated to remove traces of other radionuclides. The precipitate is transferred to a tared stainless steel planchet, dried under an infrared lamp and then in an oven, cooled in a desiccator and weighed. Samples are stored for a minimum of one week to allow for the ingrowth of radium-226 daughters and to allow for the decay of Ra-223 and its daughters. At the end of this period, samples are counted for their alpha activity and compared to the activities of standard Ra-226 solutions which have been carried through the same procedure. The detection limit of this method is 7 mBq/L at the 95% confidence level for a 100 minute counting period. This procedure was adapted from APHA 'Standard Methods' 14th ed. 1975, pp. 661-666.

Conductivity and pH

A Hatch laboratory model conductivity meter was used. The conductivity measurements are given in µmhos/cm corrected to 25°C. pH was determined using a Fisher model 291 pH meter and combination probe. The instrument was standardized with BDH buffers at pH 4 and 10.

III DESCRIPTION OF STUDY AREAS

GEOLOGY

Information on the geology of the Okanagan and West Kootenay regions was obtained primarily from maps by Little (1957, 1960, and 1961). Additional detailed data on the geological setting of the Hydraulic Lake and Blizzard uranium deposits (Kelowna and Beaverdell areas respectively) was taken from a recent map by Christopher (1978) and a report by Boyle (1979).

The generalized distribution of rock types in each of the five study areas is shown in Figs. 6 - 8. A composite lithological legend for the various bedrock units identified is given in Table 2. Precambrian metamorphic rocks (Unit A and B) occur in Kelowna and Blueberry Creek areas. In the Kelowna area they are referred to as the Monashee Group and are composed of weakly radioactive paragneiss. Paleozoic metasedimentary and metavolcanic rocks of the Anarchist Group (Unit C) are also present locally in the Kelowna area, but are most widespread near Beaverdell. Like the Monashee Group they exhibit low background radioactivity.

These units have been intruded by Nelson and Valhalla plutonic rocks. Nelson intrusives (Unit D) are Cretaceous in age and are typically composed of granodiorite, monzonite or diorite. They are an important bedrock type in all areas but Kelowna. Valhalla rocks (Unit E) are somewhat younger (Upper Cretaceous to Eocene) and generally comprise porphyritic quartz monzonites and granites. Although radiometric counts for Nelson intrusives are comparatively low, those for Valhalla rocks are considerably above local background.

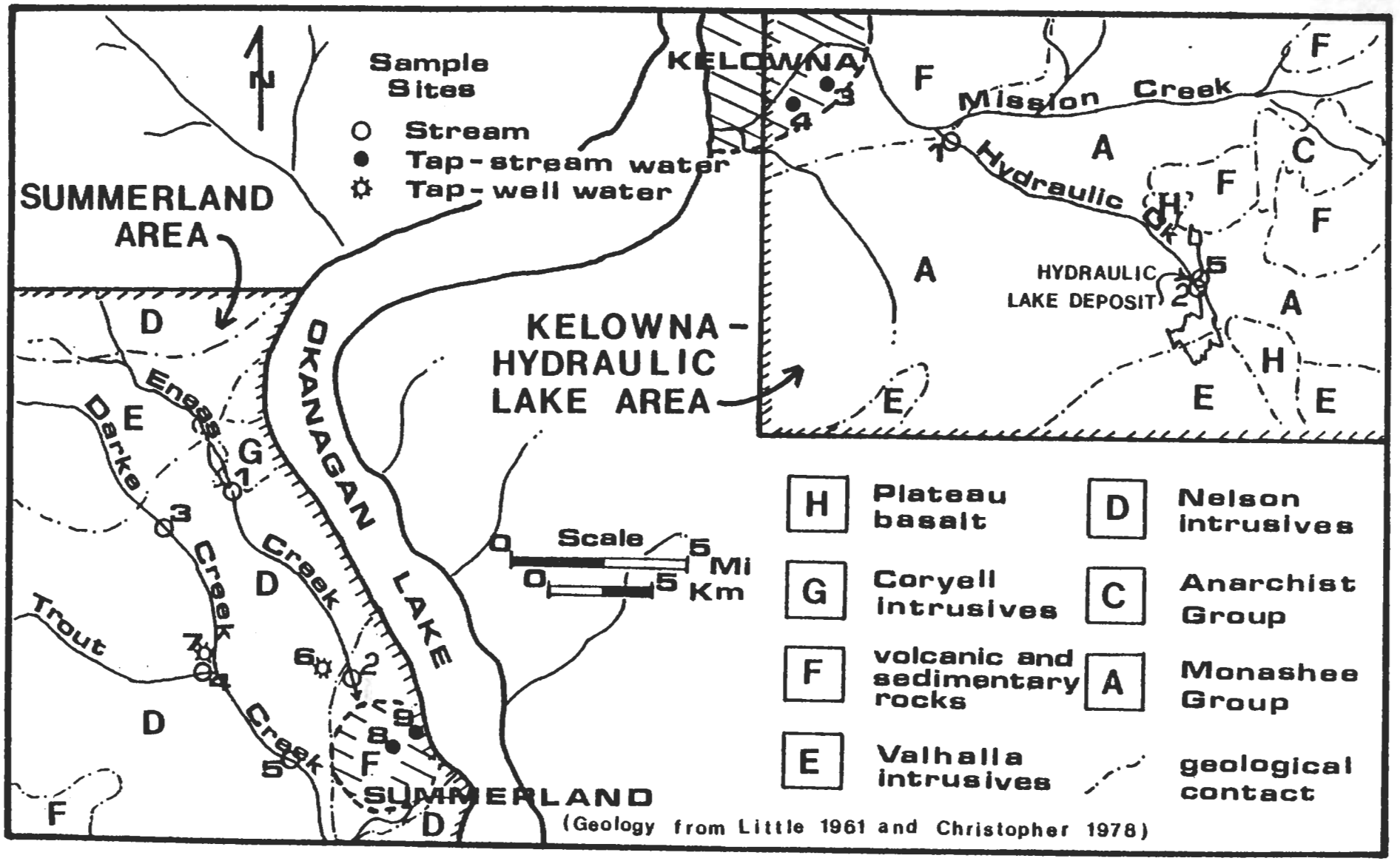


FIGURE 6. Sample site locations and geology, Summerland and Kelowna - Hydraulic Lake areas.

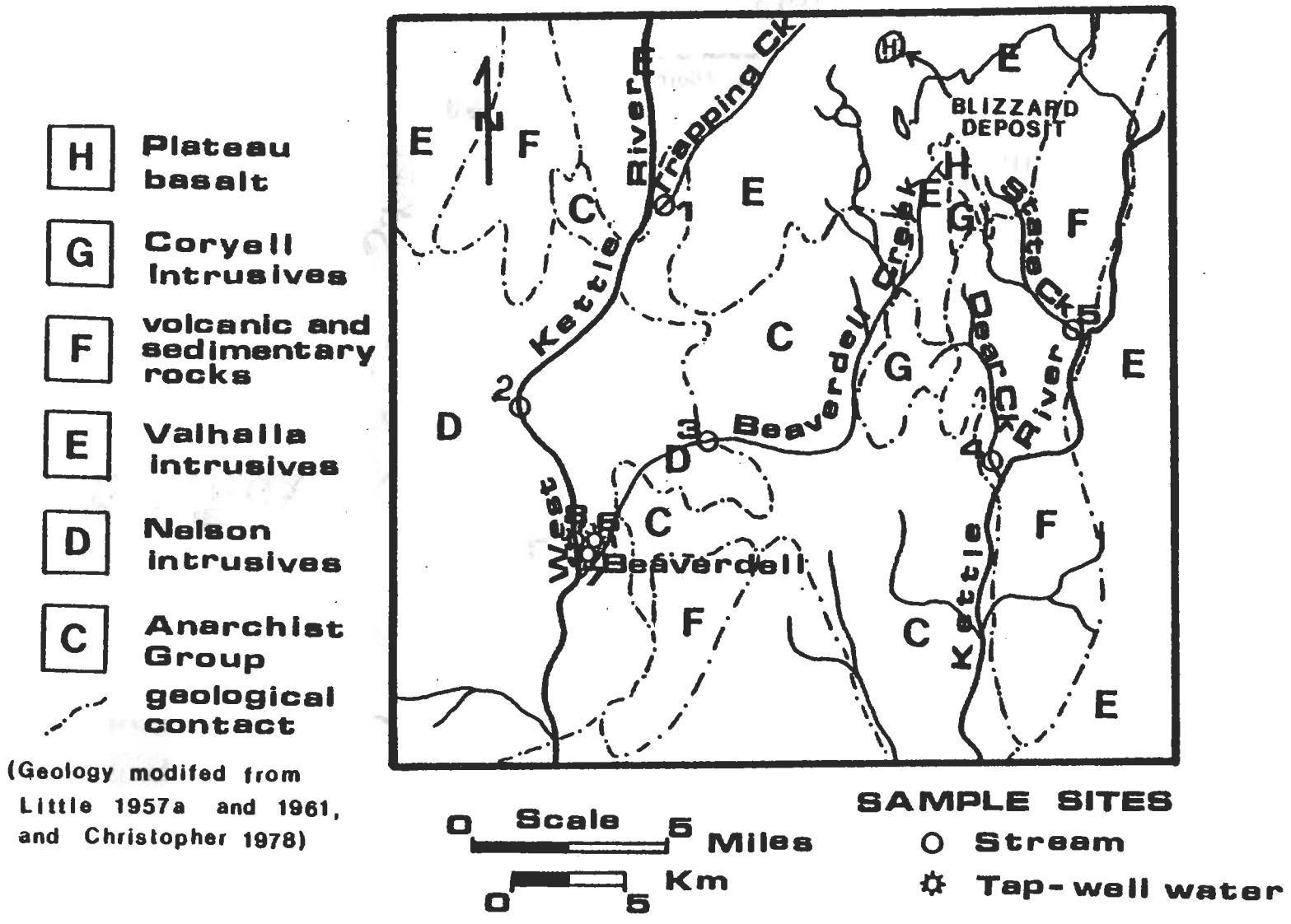


FIGURE 7. Sample site locations and geology, Beverdell area.

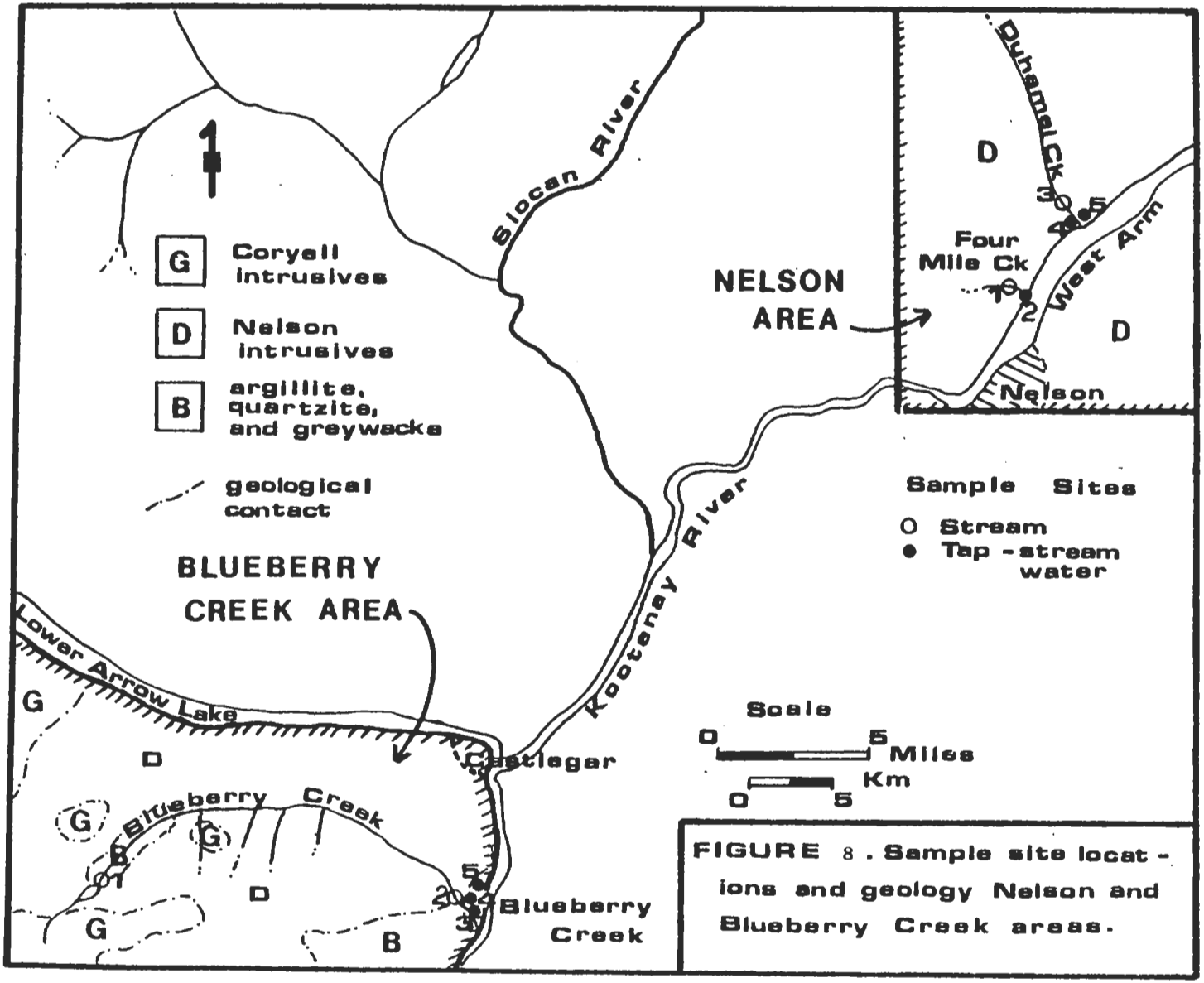


FIGURE 8. Sample site locations and geology Nelson and Blueberry Creek areas.

Table 2. Composite geological legend.

Age	Map Symbol	Name	Principal Features
CENOZOIC/TERTIARY			
	H	Plateau Basalts	olivine basalt; underlain by unconsolidated Miocene sediments which locally host uranium mineralization
	G	Coryell Intrusions	syenite, granite; high background radioactivity
	F	Kettle River Formation or Kamloops Group	rhyolite, andesite and trachyte
MESOZOIC/CRETACEOUS			
	E	Valhalla Intrusions	monzonite, granite, granodiorite; moderate background radioactivity
	D	Nelson Intrusions	granodiorite, diorite, granite, monzonite; low background radioactivity
PALEOZOIC/PERMIAN (?)			
	C	Anarchist Group	greenstone, quartzite, argillite, limestone; low background radioactivity
PRECAMBRIAN			
	B	unnamed	argillite, quartzite, greywacke
	A	Monashee Group	layered gneiss

Plutonic rocks are overlaid in places by Eocene-Oligocene volcanic-sedimentary series (Unit F). In the Beaverdell area this unit includes Kamloops Group rocks, while in the Kelowna area it is composed in part, of Kettle River Formation strata. Principal lithologies are rhyolite, andesite, trachyte, basalt, conglomerate, sandstone and shale. Locally these rocks may display strong radioactive responses, some of which, especially in the case of the lavas, are attributable to the presence of thorium (Church and Johnson, 1978).

Coryell syenites, monzonites and granites constitute the youngest intrusive unite (G). Although of limited geographic extent, Coryell rocks display a very strong radiometric background.

Plateau basalts (Unit H) are the most recent of the major lithologies recognized. They are normally flat-lying vessicular and columnar olivine basalt flows with a total thickness of up to 60 m. This unit occurs as outliers in both the Beaverdell and Kelowna areas. It is commonly underlain by unconsolidated Miocene sandstones, conglomerates and mudstones, which locally host potentially economic uranium mineralization.

MINERALIZATION

Significant uranium mineralization has been identified in both the Kelowna and Beaverdell areas. At the "Hydraulic Lake" deposit south-east of Kelowna (Fig. 6) uranium occurs in Miocene pebble conglomerates beneath Hydraulic Creek a short distance downstream from the Hydraulic Lake spillway. The deposit is covered by about 50 m of overburden, preserved from erosion by an impermeable Pleistocene boulder clay cap. Uranium-bearing minerals including ningyoite, gummite, and possibly uraninite occur in association with marcasite (FeS_2) and detrital carbonitized wood and coaly material.

A somewhat similar situation exists at the "Blizzard" deposit northeast of Beaverdell (Fig. 7), (Envirocon, 1980 Vol. 2). In this case Miocene sediments are preserved under Plateau Basalts. Uranium occurs in unconsolidated clastic sediments as saleeite ($Mg(UO_2)_2(PO_4)_2.8H_2O$) and meta-autunite ($Ca(UO_2)_2(PO_4).2\text{-}6H_2O$) as well as other as yet unidentified mineral species. Ground and surface drainage from the deposit passes mainly into Trapping Creek. Several additional smaller occurences of uranium have been recognized near the headwaters of Dear Creek.

The source of uranium is thought to have been local uranium-enriched bedrock such as Coryell and Valhalla intrusives. The model envisaged involves repeated leaching of bedrock, transportation by ground water through permeable sediments and eventual fixation and concentration of uranium by reducing, organic-rich environments.

Recently, uranium mineralization has been identified in the vicinity of Four Mile Creek near Nelson.

IV RESULTS AND DISCUSSION

URANIUM

Geographic Variations

Examination of analytical results in Tables 3 - 7, covering the period Feb/79 - Jan/80, reveals a strong geographic component in data variability. Concentrations in surface waters in the Beaverdell, Blueberry Creek, and Hydraulic Lake - Kelowna areas are generally low (<2.0 ppb) compared to those in the Summerland and the Four Mile Creek-Nelson area.

Low uranium levels (Table 4) in Hydraulic Creek water are perhaps not surprising in view of the fact that the uranium mineralization in this area (Fig. 6) occurs approximately 50 m beneath the creek bed. Absence of anomalous values in the Beaverdell area (Table 5), on the other hand, particularly in Trapping Creek, is difficult to reconcile with the fact that the Blizzard ore body (Fig. 7) is situated well above the local ground water table and should therefore be subject to the effects of leaching by surface waters. Recent detailed studies by Boyle (1979) however indicate that, although surface drainage in the immediate vicinity of mineralization is enriched in uranium (up to 18 ppb), anomalies are very quickly reduced to background values.

Well water from site 6 (Beaverdell Ranger Station) does, however, have elevated uranium levels as compared to Beaverdell surface samples. The average value over the 12 month period Feb/79 - Jan/80, is 5.4 ppb. Since this is a well sample, the results indicate that groundwater transport of uranium could have more far reaching consequences than surface drainage.

AREA: SUMMERLAND

TABLE 3

Sites:

1 Garnet Lk. Spillway
2 Eneas Cr.
3 Darke Cr.
4 Trout Cr.
5 Trout Cr. at Intake
6 Well, Eneas Cr.
7 Well, Darke Cr.
8 S.O.H.U. Office
9 Summerland Home

URANIUM (PPB)	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan./80
1	11	14	11	9.4	7.8	7.1	6.6	7.5	7.6	7.7	8.0	9.2
2	22	27	22	17	17	16	13	17	17	17	19	12
3	13	16	13	6.0	8.7	2.2	3.4	12	9.8	10	11	19
4	3.9	5.9	4.3	0.25	0.55	0.90	1.4	0.80	8.1	3.2	2.6	3.8
5	3.9	6.7	3.9	0.55	0.70	0.85	1.7	0.92	1.2	3.4	2.6	3.6
6	23	25	24	14	19	16	17	18	19	19	-	-
7	14	26	20	20	17	14	16	15	19	15	-	18
8	3.7(3.3)	5.1	4.6	0.55(1.2)	0.55	0.85	1.4	1.0	1.2(1.0)	2.5	1.6	1.5(1.8)
9+	3.6	5.0	4.3	0.70	-	-	-	-	-	-	-	-
GROSS ALPHA (mBq/ℓ)												
1	150±70	190±70	100±70	220±100	260±70	150±70	100±70	70±70	220±100	180±70	220±70	210±90
2	220±100	300±100	330±100	370±150	420±150	410±150	590±190	520±190	330±150	340±130	410±150	370±210
3	260±70	150±40	40±40	110±40	190±70	40±40	< 40	190±70	220±100	160±70	180±70	260±100
4	< 40	70±40	40±40	40±40	< 40	40±40	< 40	< 40	100±70	100±50	40±40	150±100
5	40±40	40±40	70±30	< 40	< 40	< 40	< 40	70±40	< 40	100±40	70±40	170±100
6	370±150	220±150	440±70	220±150	440±150	410±150	440±150	300±150	590±220	300±160	-	-
7	330±100	190±90	190±70	220±70	440±100	480±100	300±100	440±100	300±100	190±70	-	400±130
8	< 40(30±30)	40±40	< 40	< 40	< 40	< 40	< 40	70±40	< 40	<40	< 40	100±100
9+	70±40	< 40	40±40	40±40	-	-	-	-	-	-	-	-
GROSS BETA (mBq/ℓ)												
1	260±100	300±100	300±100	190±100	370±100	150±70	< 100	190±100	< 100	260±100	250±100	290±100
2	260±150	440±150	300±100	220±220	550±220	220±220	550±220	670±260	440±220	520±220	590±220	370±210
3	100±100	220±100	220±100	220±100	370±100	300±100	150±100	370±100	220±100	320±100	300±100	260±100
4	< 100	< 100	< 100	190±100	< 100	< 100	< 100	< 100	100±100	150±100	180±100	150±100
5	< 100	100±100	190±100	100±100	100±100	100±100	190±100	< 100	150±100	180±100	180±100	170±100
6	370±220	550±220	630±100	< 100	440±260	410±220	520±220	520±220	810±220	840±220	-	-
7	220±100	330±100	330±100	370±100	330±100	440±100	300±100	370±100	440±150	330±100	-	440±130
8	300±100(190±100)	220±100	190±100	< 100	100±100	< 100	100±100	< 100	190±100	160±100	100±100	100±100
9+	260±100	< 100	< 100	< 100	-	-	-	-	-	-	-	-
CONDUCTIVITY (μmhos/cm)												
1	360	370	360	360	355	350	310	300	325	350	350	360
2	480	470	470	540	550	580	580	560	575	560	550	550
3	300	300	300	200	220	170	210	350	350	330	330	330
4	270	150	160	60	90	110	140	92	160	200	170	200
5	170	150	160	60	90	110	135	90	160	190	170	200
6	600	600	620	640	590	590	620	600	650	670	-	-
7	340	350	380	370	370	370	380	380	380	360	-	350
8	170(163)	155	160	70(75)	85	115	130	120	150(150)	170	165	190(190)
9+	170	160	160	70	-	-	-	-	-	-	-	-
pH												
1	7.4	7.7	7.3	7.8	8.1	8.1	7.7	8.3	8.0	8.0	7.9	7.4
2	7.9	8.1	7.7	7.8	7.9	8.1	8.0	7.8	7.8	7.8	8.0	7.4
3	7.9	8.0	7.5	7.5	7.8	7.8	8.0	8.0	7.8	7.9	8.0	7.6
4	7.8	7.9	7.2	7.1	7.7	8.0	8.2	7.7	7.6	7.8	7.9	7.5
5	7.6	7.7	7.2	7.0	7.7	7.9	8.2	7.5	7.7	7.8	7.9	7.5
6	7.1	7.2	6.9	7.5	7.4	7.6	7.5	7.0	7.2	7.7	-	-
7	7.5	7.6	7.1	7.6	7.6	7.8	7.6	7.8	7.6	7.9	-	7.8
8	7.2(7.5)	7.4	7.0	6.9(7.8)	7.3	7.6	7.7	7.8	7.4(7.3)	7.4	7.5	7.2(7.2)
9+	7.1	7.1	7.0	7.0	-	-	-	-	-	-	-	-
FLOW (m^3/sec)												
5	0.33	0.54	0.64	9.2	0.75	0.02	0.10	0.17	-	-	-	-

TABLE 4

AREA: KELOWNA (KL)

Sites:
1 Hydraulic Cr. at Intake
2 Hydraulic Lk. at Spillway
3 S.E.K.I.D. Office
4 Kelowna Home
5 Fish Cr.

URANIUM (PPB)	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.
1	0.30	0.35	0.45	0.50	0.70	0.60	0.20	-	0.15	-	0.30	0.30
2	0.30	0.45	0.25	0.45	0.65	0.45	1.10	-	0.15	-	0.05	0.10
3	0.30(0.30)	0.80(0.10)	0.55(0.30)	0.45(0.50)	0.60	0.55	1.10	-	0.20	-	0.35	0.40
4+	0.30(0.30)	0.90(0.10)	0.55(0.30)	0.20(0.40)	-	-	-	-	-	-	-	-
5+	0.10	0.65	0.40	0.15	-	-	-	-	-	-	-	-
GROSS ALPHA (mBq/ℓ)												
1	<40	<40	<40	<40	<40	<40	<40	-	<40	-	<40	<40
2	<40	<40	<40	<40	<40	<40	<40	-	<40	-	<40	<40
3	<40(<40)	<40	<40	<40	<40	<40	<40	-	<40	-	<40	<40
4+	<40(<40)	<40	<40	<40	-	-	-	-	-	-	-	-
5+	<40	<40	<40	<40	-	-	-	-	-	-	-	-
GROSS BETA (mBq/ℓ)												
1	260±100	100±100	100±100	<100	<100	<100	<100	-	<100	-	150±100	140±100
2	190±80	150±100	<100	<100	150±100	<100	<100	-	<100	-	150±100	180±100
3	<100(<100)	<100	150±100	<100	190±100	<100	150±100	-	<100	-	180±100	120±100
4+	<100(150±100)	150±100	<100	100±100	-	-	-	-	-	-	-	-
5+	<100	150±100	100±100	<100	-	-	-	-	-	-	-	-
COND. (μmhos/cm)												
1	-	160	120	65	50	45	58	-	80	-	230	260
	-	7.2	6.9	6.8	6.4	6.6	7.4	-	7.1	-	8.0	7.7
2	-	60	130	35	35	35	42	-	50	-	38	53
	-	6.2	6.5	6.7	6.1	6.1	7.0	-	6.6	-	7.0	6.6
3	(155)	160(144)	150	65(65)	50	45	65	-	80	-	195	240
	(7.7)	7.1(7.6)	6.7	6.9(7.2)	6.3	6.2	6.9	-	7.1	-	7.3	7.7
4+	-	175(152)	150	65(65)	-	-	-	-	-	-	-	-
	-	7.5(8.0)	6.7	6.7(7.7)	-	-	-	-	-	-	-	-
5+	-	65	55	55	-	-	-	-	-	-	-	-
	-	6.8	6.3	7.0	-	-	-	-	-	-	-	-

+ Sites not analysed after May, 1979.
Values in brackets are averages of composite results.

TABLE 5

AREA: BEAVERDELL (BR)

Sites:

1 Trapping Creek
2+ West Kettle River
3 Beaverdell Creek
4 Dear Creek
5 State Creek
6 Beaverdell Ranger Station
7+ Tamarack Lodge
8+ Beaverdell Home

URANIUM (PPB)	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan./80
1	1.0	1.3	0.75	0.15	0.40	0.40	0.30	0.25	0.30	1.2	0.2	0.3
2+	-	1.7	0.75	0.45	-	-	-	-	-	-	-	-
3	2.3	1.7	1.0	0.35	1.3	1.3	1.4	2.0	1.4	3.0	1.8	2.8
4	-	0.90	0.95	0.25	0.40	0.60	0.70	-	0.70	-	-	-
5	-	1.0	-	0.30	0.60	0.70	1.0	1.7	1.1	-	-	-
6	1.9	9.2	6.0	3.5(5.0)	6.8	5.1	4.5	6.4	4.6	7.0	5.4	4.6
7+	-	10	5.9	-	-	-	-	-	-	-	-	-
8+	-	-	(8.2)	2.9(3.5)	-	-	-	-	-	-	-	-
GROSS ALPHA (mBq/ℓ)												
1	40±40	<40	70±40	40±40	<40	<40	<40	<40	<40	40±40	<40	40±40
2+	-	<40	40±40	<40	-	-	-	-	-	-	-	-
3	<40	<40	<40	<40	<40	<40	<40	<40	<40	120±60	70±40	70±40
4	-	<40	<40	<40	<40	<40	<40	<40	<40	-	-	-
5	<40	<40	-	<40	110±70	<40	<40	<40	<40	-	-	-
6	-	150±70	70±40	100±70(<40)	-	150±70	<40	40±40	100±70	120±70	150±70	100±40
7+	-	70±70	<40	-	-	-	-	-	-	-	-	-
8+	-	-	-	100±80(220±80)	-	-	-	-	-	-	-	-
GROSS BETA (mBq/ℓ)												
1	220±100	<100	190±100	<100	<100	<100	480±100	<100	<100	<100	<100	400±100
2+	-	<100	150±100	150±100	-	-	-	-	-	-	-	-
3	<100	<100	<100	100±100	100±100	100±100	<100	<100	150±100	100±100	150±100	320±100
4	-	<100	190±100	<100	<100	<100	<100	-	<100	-	-	-
5	<100	<100	-	<100	100±100	100±100	150±100	100±100	<100	-	-	-
6	-	190±100	190±100	<100(<100)	100±100	100±100	<100	<100	300±100	260±100	150±100	140±100
7+	-	100±100	300±100	-	-	-	-	-	-	-	-	-
8+	-	-	-	100(220±160)	-	-	-	-	-	-	-	-
CONDUCTIVITY (μmhos/cm)												
1	185	85	80	30	40	50	76	92	75	82	69	82
2+	-	85	75	35	-	-	-	-	-	-	-	-
3	250	175	115	115	180	230	250	250	250	280	270	280
4	-	150	115	130	160	175	230	-	230	-	-	-
5	-	180	-	115	165	195	250	250	260	-	-	-
6	-	400	390	400(400)	410	420	410	400	425	440	440	430
7+	-	380	380	-	-	-	-	-	-	-	-	-
8+	-	-	(410)	420(410)	-	-	-	-	-	-	-	-
pH												
1	7.6	7.4	7.3	6.9	5.9	7.5	7.6	7.3	7.5	7.1	7.6	7.5
2+	-	7.1	7.6	7.0	-	-	-	-	-	-	-	-
3	7.5	7.9	7.8	7.7	7.1	8.1	7.7	8.0	8.0	7.6	7.8	7.8
4	-	8.0	7.8	8.0	7.0	8.0	7.5	-	7.9	-	-	-
5	-	8.0	-	8.0	7.0	8.1	7.7	7.7	8.1	-	-	-
6	-	7.2	7.3	8.1(8.0)	6.4	7.2	7.3	7.0	7.3	7.0	7.2	7.3
7+	-	7.2	7.4	-	-	-	-	-	-	-	-	-
8+	-	-	(8.0)	8.0(8.4)	-	-	-	-	-	-	-	-
FLOWS (m^3/sec)												
1	0.19	0.27	1.8	9.4	1.3	0.44	0.14	-	-	-	-	-
3	-	-	1.3	1.1	0.18	0.10	0.03	0.05	-	-	-	-

TABLE 6

AREA: BLUEBERRY CREEK (BC)

Sites:
1 Blueberry Creek at Lake
2 Blueberry Creek at Intake
3, 4, & 5 Blueberry Creek Homes

URANIUM (PPB)	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan./80
1+	0.20	0.10	0.15	0.05	-	-	-	-	-	-	-	-
2	0.15	0.20	0.25	0.20	0.20	-	0.08	0.20	0.30	0.80	-	0.10
3+	0.25(0.30)	0.20	0.20	0.20	-	-	-	-	-	-	-	-
4	0.25	0.15	0.35	0.20	0.15	0.30	0.10	0.15	0.40	0.75	0.80	0.15
5+	0.70	0.15	0.25	0.20	-	-	-	-	-	-	-	-
GROSS ALPHA (mBq/ℓ)												
1+	<40	<40	<40	<40	-	-	-	-	-	-	-	-
2	<40	<40	<40	<40	<40	-	<40	<40	<40	<40	<40	<40
3+	<40(30±30)	<40	<40	<40	-	-	-	-	-	-	-	-
4	<40	<40	<40	<40	<40	70±40	<40	<40	<40	60±20	<40	<40
5+	<40	<40	<40	<40	-	-	-	-	-	-	-	-
GROSS BETA (mBq/ℓ)												
1+	<100	<100	100±100	<100	-	-	-	-	-	-	-	-
2	<100	<100	100±100	<100	<100	-	<100	<100	<100	150±90	<100	<100
3+	<100(190±100)	<100	150±100	<100	-	-	-	-	-	-	-	-
4	150±100	<100	150±100	<100	<100	220±100	<100	<100	<100	100±100	<100	<100
5+	150±100	<100	100±100	100±100	-	-	-	-	-	-	-	-
COND. (μmhos/cm)/pH												
1+	91	90	95	65	-	-	-	-	-	-	-	-
	7.5	6.8	6.9	7.8	-	-	-	-	-	-	-	-
2	116	110	90	65	60	-	99	80	120	88	102	110
	7.2	7.4	7.4	7.8	7.3	-	7.0	7.2	7.4	7.1	6.8	7.6
3+	116(117)	110	90	50	-	-	-	-	-	-	-	-
	7.1(7.1)	7.4	7.2	7.6	-	-	-	-	-	-	-	-
4	110	115	95	55	60	85	105	96	125	92	120	105
	7.3	7.2	7.1	7.8	7.2	7.5	7.0	7.4	7.5	7.0	7.4	7.5
5+	110	115	90	50	-	-	-	-	-	-	-	-
	7.1	7.1	7.2	7.7	-	-	-	-	-	-	-	-

TABLE 7

AREA: NELSON

Sites:
1 Four Mile Cr.
2 Four Mile Cr. Home
3 Duhamel Cr.
4 MacDonald Landing School
5 MacDonald Landing Home

URANIUM (PPB)	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan./80
1+	41	7.0	3.8	1.2	-	-	-	-	-	-	-	-
2	43(40)	7.2	3.8	1.2(1.4)	4.1	6.2	16	26(22)	4.6(6.0)	22	5.6(16)	22
3+	2.8	2.6	1.5	0.45	-	-	-	-	-	-	-	-
4	2.4	2.6	1.6	0.36	0.60	1.0	1.1	1.7	0.35	2.4	0.75	1.2
5+	2.6(2.7)	2.6	1.6	0.50	-	-	-	-	-	-	-	-
GROSS ALPHA (mBq/ℓ)												
1+	740±100	100±40	70±50	40±40	-	-	-	-	-	-	-	-
2	700±70(590±70)	190±40	70±50	<40	70±40	190±40	370±70	330±70	220±70	520±70	150±40	520±70
3+	70±40	<40	40±40	<40	-	-	-	-	-	-	-	-
4	70±40	<40	40±40	<40	<40	<40	<40	40±40	<40	<40	40	50±40
5+	40±40(<40)	<40	40±40	<40	-	-	-	-	-	-	-	-
GROSS BETA (mBq/ℓ)												
1+	440±100	150±100	100±100	<100	-	-	-	-	-	-	-	-
2	410±100(630±100)	100±100	100±100	<100	150±100	220±100	<100	410±100	370±100	400±100	300±100	400±100
3+	<100	100±100	100±100	<100	-	-	-	-	-	-	-	-
4	<100	<100	<100	<100	<100	<100	150±100	<100	100±100	<100	100±100	170±100
5+	150±100(100±100)	100±100	<100	<100	-	-	-	-	-	-	-	-
COND. (μmhos/cm)/pH												
1+	107	70	65	65	-	-	-	-	-	-	-	-
	7.6	7.7	7.5	7.8	-	-	-	-	-	-	-	-
2	105(112)	70	65	65(50)	80	95	115	115(115)	112(117)	120	75 (102)	112
	7.6(7.5)	7.5	7.3	7.8(7.7)	7.1	7.3	7.7	7.4(7.6)	7.6(7.6)	7.4	7.5(6.7)	7.0
3+	77	75	70	50	-	-	-	-	-	-	-	-
	7.6	7.6	7.5	7.6	-	-	-	-	-	-	-	-
4	79	80	70	55	50	70	91	90	85	90	74	87
	7.6	7.7	7.5	7.8	6.7	7.2	7.8	7.7	7.8	7.5	7.7	7.0
5+	77(87)	80	70	50	-	-	-	-	-	-	-	-
	7.5(7.4)	7.9	7.5	7.7	-	-	-	-	-	-	-	-

+ Sites not analysed after May, 1979.
Values in brackets are averages of composite results.

The recently released Envirocon report on the Baseline Inventory of the Blizzard Property (Envirocon, 1980) supports these findings. An excerpt from their summary is as follows. "The quality of surface water showed few appreciable changes with distance from the Blizzard ore body although uranium content decreased farther from the deposit. In ground water, concentrations of most water quality parameters, but particularly radiometric parameters, were higher than in surface water".

There were a number of instances where sampling for the study reported here and the Envirocon study overlapped. The two periods involved were March and June at Trapping Creek and State Creek. The means of the two data sets agreed within 20 percent. The sampling locations on Beaverdell Creek did not coincide. The samples from the closest stations, however, gave results which agreed within a factor of 2.

Low uranium concentrations in Blueberry Creek (Table 6) are consistent with the absence of local uranium deposits and low background radioactivity reported for the Nelson intrusives (Boyle, 1979) which are the primary bedrock type. Both Four Mile and Duhamel Creeks north of Nelson are also underlaid by Nelson plutonic rocks. Although values for Duhamel Creek (Table 7) tend to be low (0.5 - 2.5 ppb) those for Four Mile Creek may, depending upon the time of sampling, be highly anomalous (maximum value 43 ppb). Further studies are required to identify the source of the enhanced uranium concentrations in Four Mile Creek.

In the Summerland area (Table 3) both surface and ground water in Eneas and Darke Creeks are characterized by relatively stable, elevated uranium values (up to 27

ppb). Concentrations in Trout Creek, which supplies most of Summerland's drinking water, however, are generally much lower (0.25 - 6.7 ppb). It is interesting to note that values for Trout Creek do not increase noticeably downstream of its confluence with Darke Creek (Fig. 3), indicating a strong dilution effect.

High conductivity values for Eneas and Darke Creeks indicate that many elements in addition to uranium, are leached in the local environment. Since economic uranium mineralization has not been reported in this area, anomalous values are likely related to enhanced background concentrations in Coryell, Valhalla and/or Nelson bedrock. D. R. Boyle (pers. comm.) has suggested that these elevated background values are in turn related to local fault patterns.

Within individual study areas a few specific comparisons can be made:

(i) Surface vs ground water: On the basis of the rather limited data summarized in Table 8, uranium concentrations in ground water appear to be generally equal to or greater than those for associated surface water.

Both the Beaverdell Creek and Eneas Creek wells tap unconsolidated near-surface aquifers. The Darke Creek well, on the other hand, penetrates over 145 m into bedrock. The high ratio of ground to surface water uranium content (average ratio 4.0) for Beaverdell Creek indicated that local ground water contributes very little to the river's flow at this point. In Eneas Creek however, where concentration ratios range between 0.8 and 1.3, ground water would appear to be an important source of uranium in creek discharge.

TABLE 8 URANIUM CONCENTRATIONS IN GROUND AND ASSOCIATED SURFACE WATER

SAMPLE NUMBER			RATIO OF CONCENTRATIONS ground/surface											
Area	Site	ground water/ surface water	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan./80
Beaverdell	Beaverdell Creek	6/3	0.8	5.4	6.0	10	5.2	3.9	3.2	3.2	3.3	2.3	3.0	1.6
Summerland	Eneas Creek	6/2	1.1	0.9	1.1	0.8	1.1	1.0	1.3	1.0	1.1	1.1	-	-
	Darke Creek	7/3	1.1	1.7	1.6	3.4	2.0	6.3	4.7	1.2	1.9	1.5	-	0.9

NOTE: Depths to top of aquifiers are:

Beaverdell site	6	20 m
Summerland site	6	3 m
	7	175 m

(ii) Surface water at different sites on the same stream: Samples were obtained from two separate sites on each of Blueberry, Hydraulic and Eneas Creeks. Distances between sites ranged from about 10 km for Hydraulic and Eneas Creeks to 25 km for Blueberry Creek (Figs. 3 and 5). At both Hydraulic and Blueberry Creeks, where total uranium concentrations are low (<1.0 ppb), little difference was observed between upstream and downstream values. This is consistent with National Geochemical Reconnaissance Program data which show that generally uranium levels vary only slightly along streams measuring up to several tens of kilometers in length.

Eneas Creek is exceptional in that there is a remarkably constant nearly twofold increase in uranium levels (and conductivity) from the Garnet Lake spillway to the next sample site 10 km downstream. Examination of URP map, NTS area 82 E, map data reveals a very pronounced trend for uranium values for both Eneas and Darke Creeks to increase systematically along their lengths. Although it has long been recognized that the content of dissolved matter in river water tends to increase from source to mouth this situation is not typical of streams.

This area has been the subject of very recent investigations regarding the extent and form of uranium mineralization (Church, 1979).

(iii) Creek vs tap water: In all areas but Beaverdell it is possible to compare data on uranium levels in surface streams with tap water derived from these streams. Examination of data in Tables 3 - 7 shows that there is little or no difference in concentrations observed in these two

types of samples. This result is not surprising in view of the fact that, for the water supplies examined, treatment generally involves only coarse screening and addition of small amounts of chlorine. It is an important observation, however, in that sampling logistics can be greatly improved.

(iv) Tap vs tap water within the same municipality: There is generally little difference between concentrations for tap water from different households in the same community (Table 3 - 7). In particular it is interesting to note that values for one home at Blueberry Creek (site 4), which is equipped with a 5 μm inline water filter, are not noticably below those for other homes in the area.

Temporal Variations

An attempt has been made (Table 9) to summarize data on apparent monthly compositional variations over the twelve month period at each of the sites being monitored. Ten sites have consistently shown measurable differences over the observation period. These differences include not only temporal variation but also sampling and analytical variability. Figures 9 - 14 show plots of the data by month. The mean value for that period is indicated by a line and dotted lines show an upper and lower limit of estimated sampling and analytical variability. Values lying outside of these limits should be an indication of the temporal nature of the uranium concentration at the sampling points.

As a rough estimate, the analytical variability for uranium is taken as $\pm$ 10% above 1 ppb based on our own precision determination on this and other projects.

TABLE 9 MEANS, STANDARD DEVIATIONS, AND EXTREMES

		Uranium (ppb)			Gross Alpha (mBq/ℓ)			Gross Beta (mBq/ℓ)			Cond. (μmhos/cm)			pH		
	n	$\bar{x}\pm\sigma$	Min	Max	$\bar{x}\pm\sigma$	Min	Max	$\bar{x}\pm\sigma$	Min	Max	$\bar{x}\pm\sigma$	Min	Max	$\bar{x}\pm\sigma$	Min	Max
Blueberry Creek																
2 Blueberry Cr. at Intake	11	0.26±0.20	0.15	0.80	<40	<40	<40	<100	<100	150	92±20	60	120	7.3±0.2	6.8	7.8
4 Blueberry Cr. Home	12	0.28±0.18	0.10	0.75	<40	<40	70	<100	<100	220	94±20	55	115	7.3±0.2	7.0	7.8
Beaverdell																
1 Trapping Cr.	12	0.60±0.40	0.20	1.3	<40	<40	70	120±120	<100	480	80±40	30	185	7.2±0.5	5.9	7.6
3 Beaverdell Cr.	12	1.6±0.7	0.35	2.8	<40	<40	140	<100	<100	320	210±56	115	280	7.7±0.3	7.1	8.1
4 Dear Cr.	7	0.65±0.20	0.25	0.95	<40	<40	<40	<100	<100	190	170±42	115	230	7.7±0.3	7.0	8.0
5 State Cr.	7	0.90±0.40	0.30	1.7	<40	<40	100	<100	<100	150	200±50	115	260	7.8±0.4	7.0	8.1
6 Beaverdell Ranger Station	12	5.5±1.9	1.9	9.2	80±40	<40	150	150±80	<100	300	410±10	390	440	7.2±0.4	6.4	8.1
Kelowna																
1 Hydraulic Cr. at Intake	10	0.40±0.18	0.15	0.70	<40	<40	<40	<100	<100	260	82±40	45	260	6.9±0.3	6.4	8.0
2 Hydraulic Lk. at Spillway	10	0.50±0.27	0.05	1.1	<40	<40	<40	<100	<100	190	55±31	35	130	6.4±0.3	6.1	7.0
3 S.E.K.I.D. Office	10	0.57±0.26	0.20	1.1	<40	<40	<40	<100	<100	190	87±44	45	240	6.7±0.3	6.2	7.7
Nelson																
2 Four Mile Cr. Home	12	13±13	1.2	43	260±200	<40	700	230±130	<100	400	94±21	65	120	7.5±0.2	7.0	7.6
4 MacDonald Landing School	12	1.4±0.8	0.35	2.6	<40	<40	70	<100	<100	170	76±14	50	90	7.5±0.3	6.7	7.8
Summerland																
1 Garnet Lk. Spillway	12	9.0±2.2	6.6	14	160±50	100	220	220±100	<100	300	340±22	300	370	7.8±0.3	7.3	8.1
2 Eneas Cr.	12	18±4	13	27	380±100	220	590	400±140	220	670	540±43	470	580	7.9±0.1	7.4	8.1
3 DArke Cr.	12	9.4±4.2	3.4	19	130±70	<40	280	250±80	100	370	260±103	170	350	7.8±0.2	7.5	8.0
4 Trout Cr.	12	2.9±2.5	0.25	6.7	40±30	<40	100	<100	<100	190	140±58	60	270	7.7±0.3	7.1	8.2
5 Trout Cr. at Intake	12	2.4±1.9	0.55	6.7	<40	<40	100	120±100	<100	190	130±40	60	190	7.6±0.3	7.0	8.2
6 Well, Eneas Cr.	10	19±3	16	25	370±100	220	590	510±205	<100	835	620±30	590	670	7.3±0.2	6.9	7.7
7 Well, Darke Cr.	11	18±3.6	14	26	300±100	190	480	340±70	220	440	370±15	340	380	7.6±0.2	7.1	7.9
8 S.O.H.U. Office	12	2.1±1.6	0.55	5.1	<40	<40	70	130±80	<100	300	130±30	70	190	7.4±0.3	6.9	7.8

FIG 9 SUMMERLAND GARNET LK. SPILLWAY

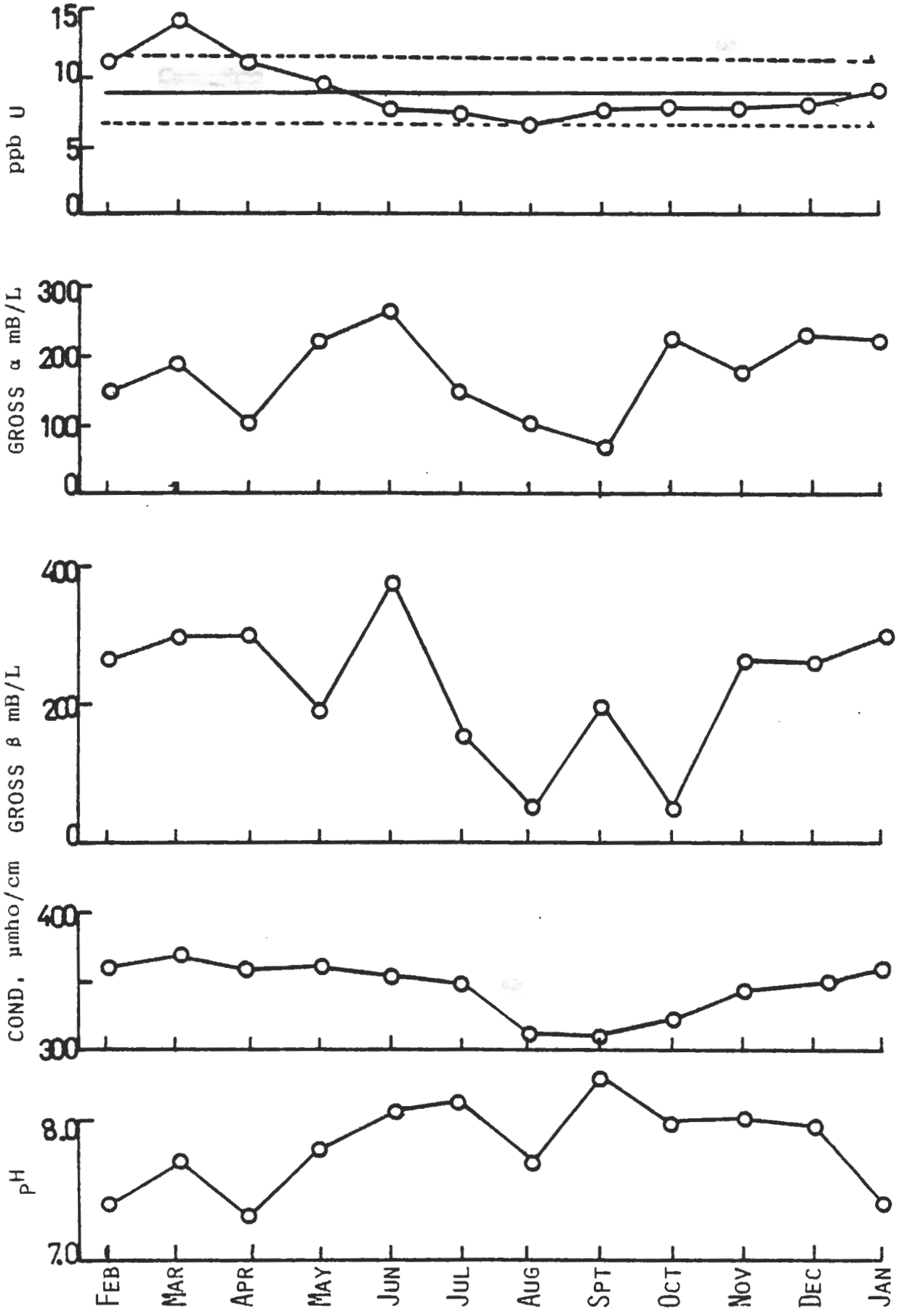


FIG 10 ○ SUMMERLAND ENEAS CREEK
△ ENEAS CREEK WELL

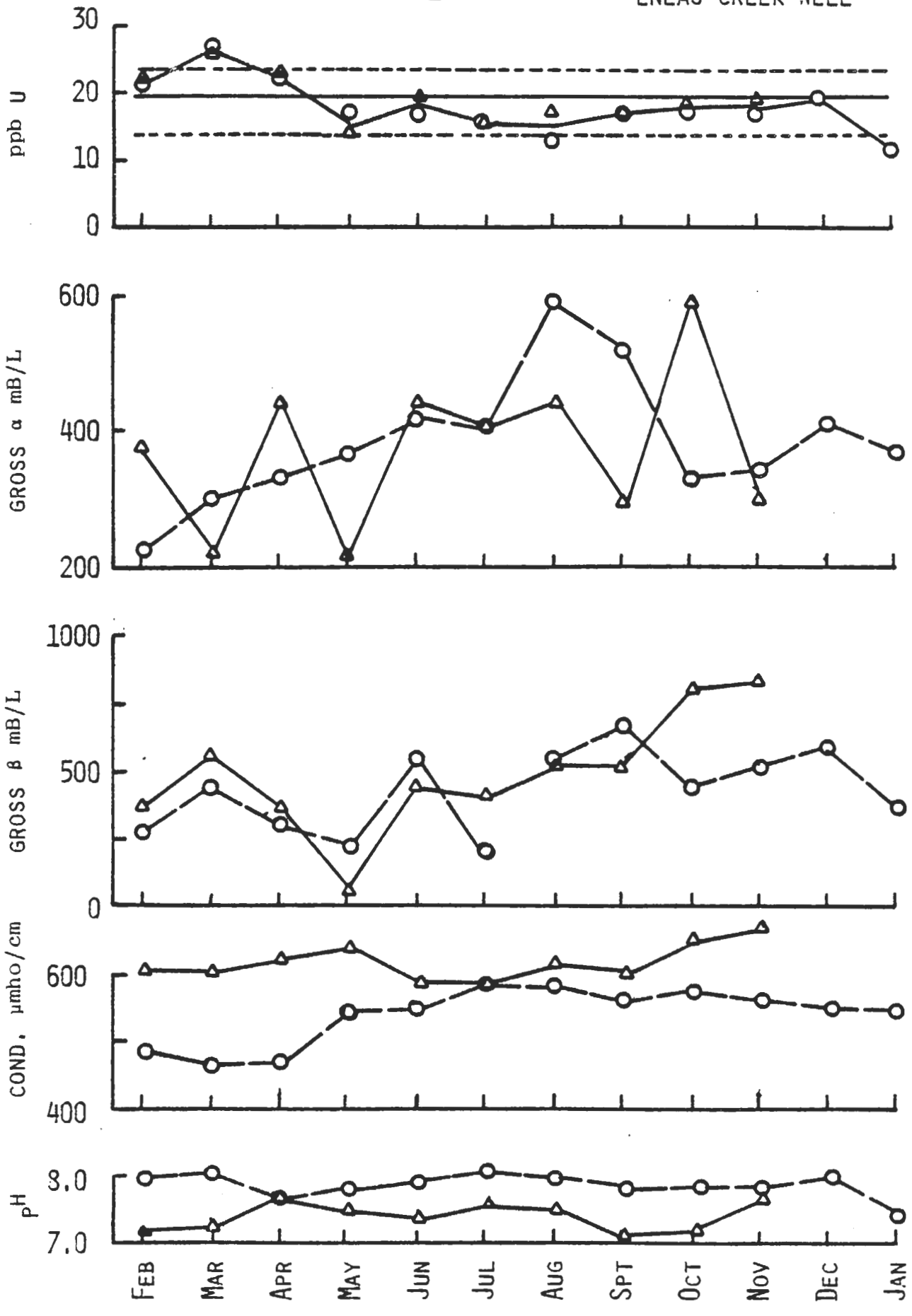


FIG 11 ○ SUMMERLAND DARKE CREEK
△ DARKE CREEK WELL

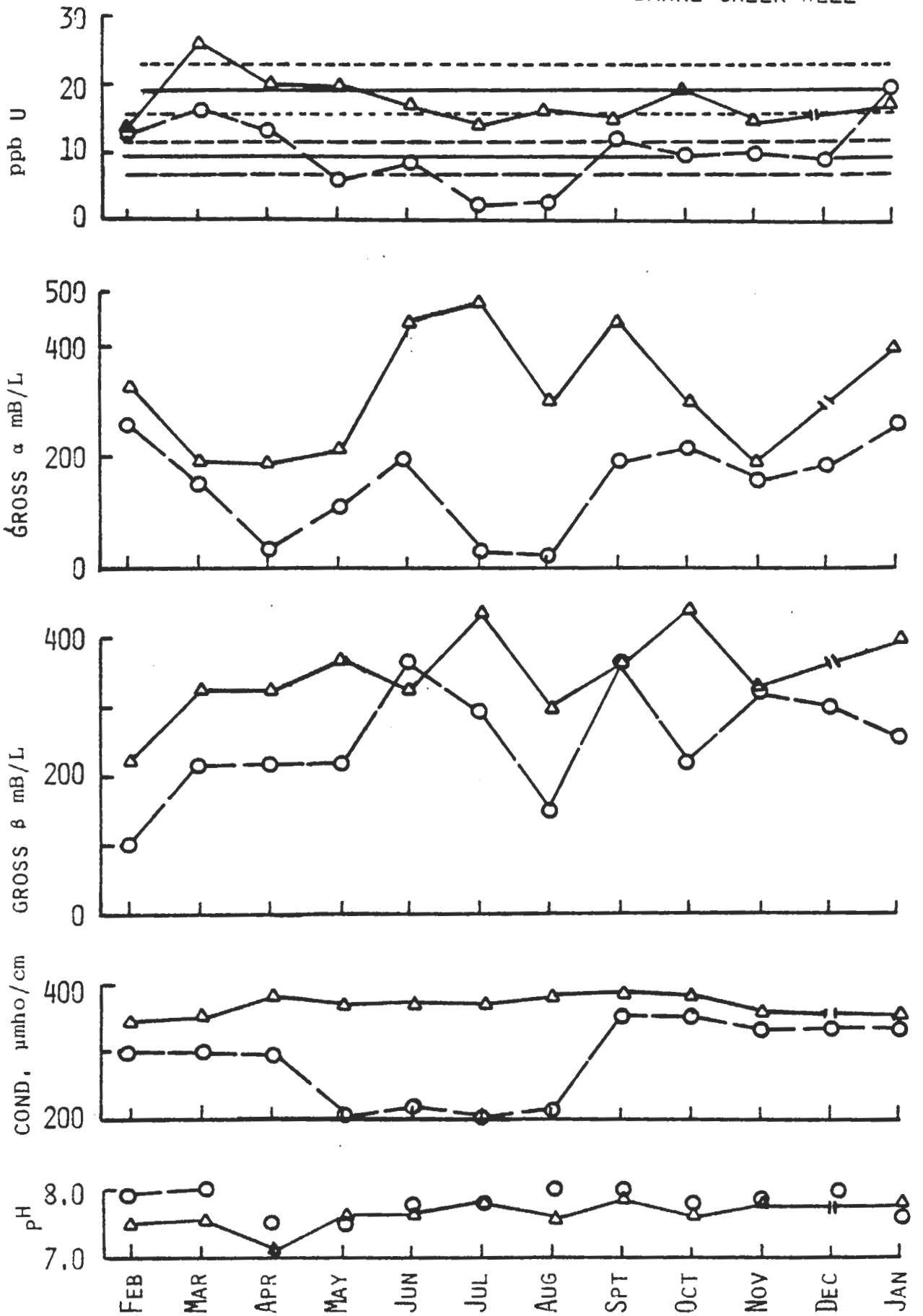


FIG 12 ○ SUMMERLAND △ TROUT CREEK □ TROUT CREEK AT INTAKE S.O.H.U. OFFICE

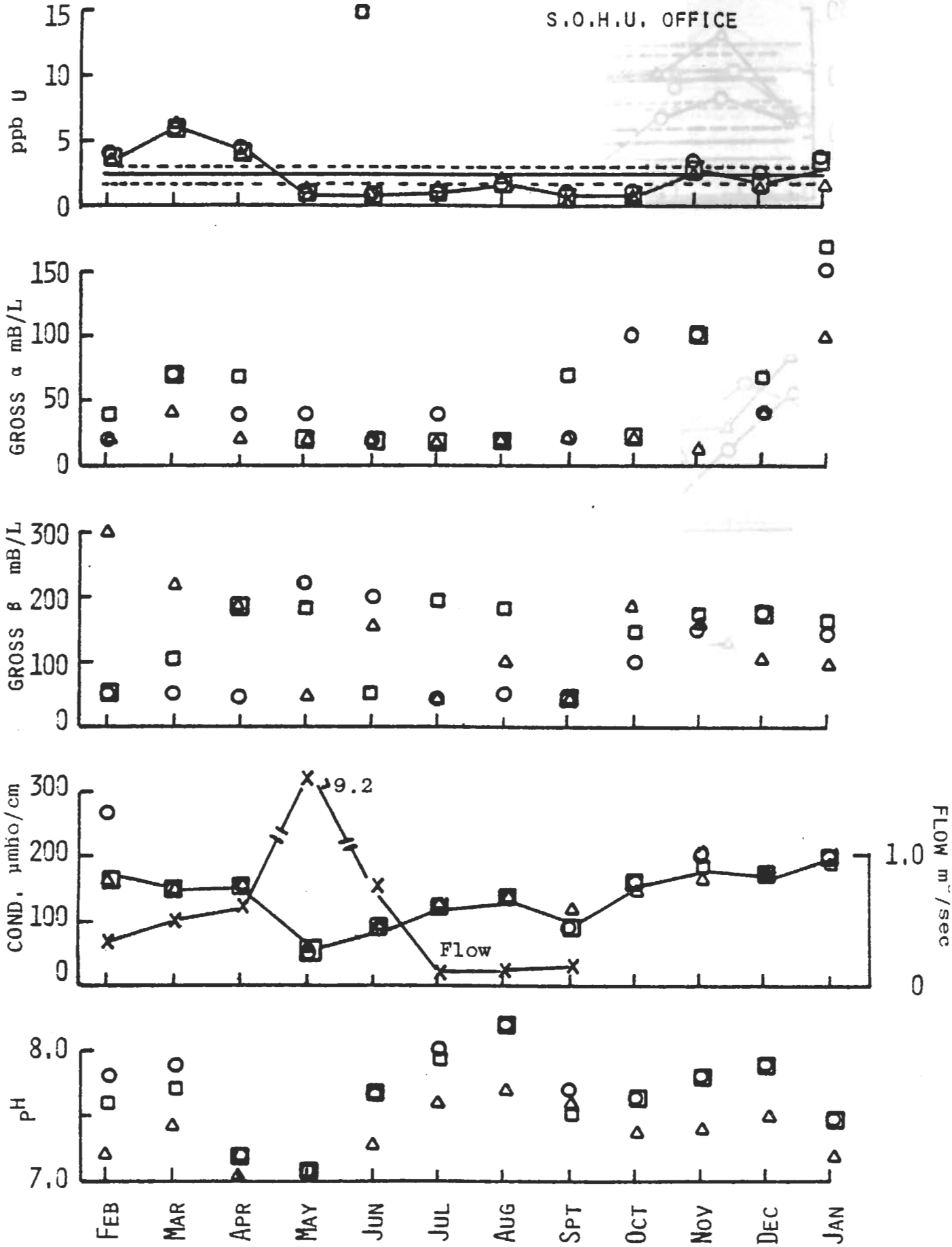


FIG 13 BEAVERDELL RANGER STATION

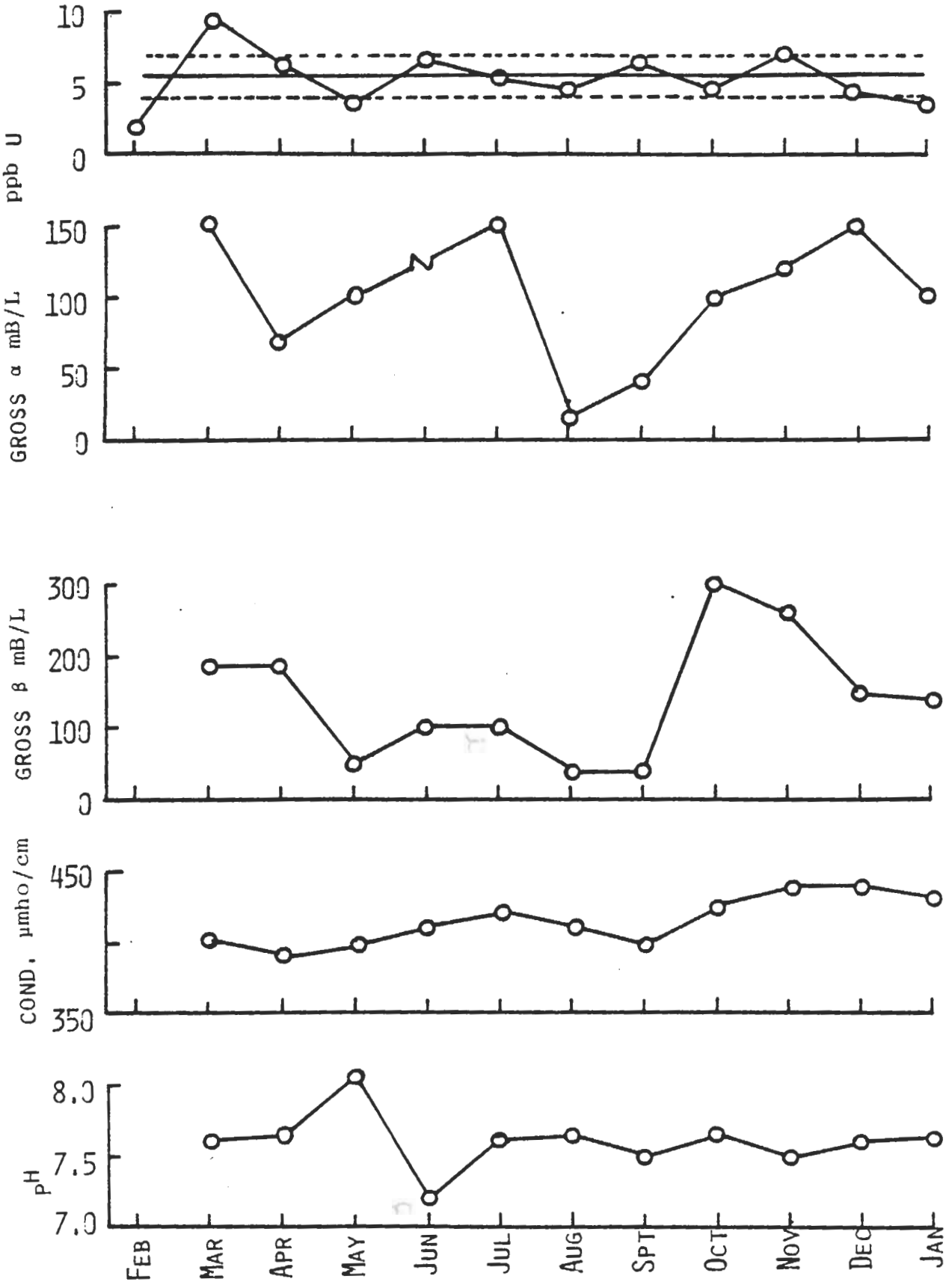
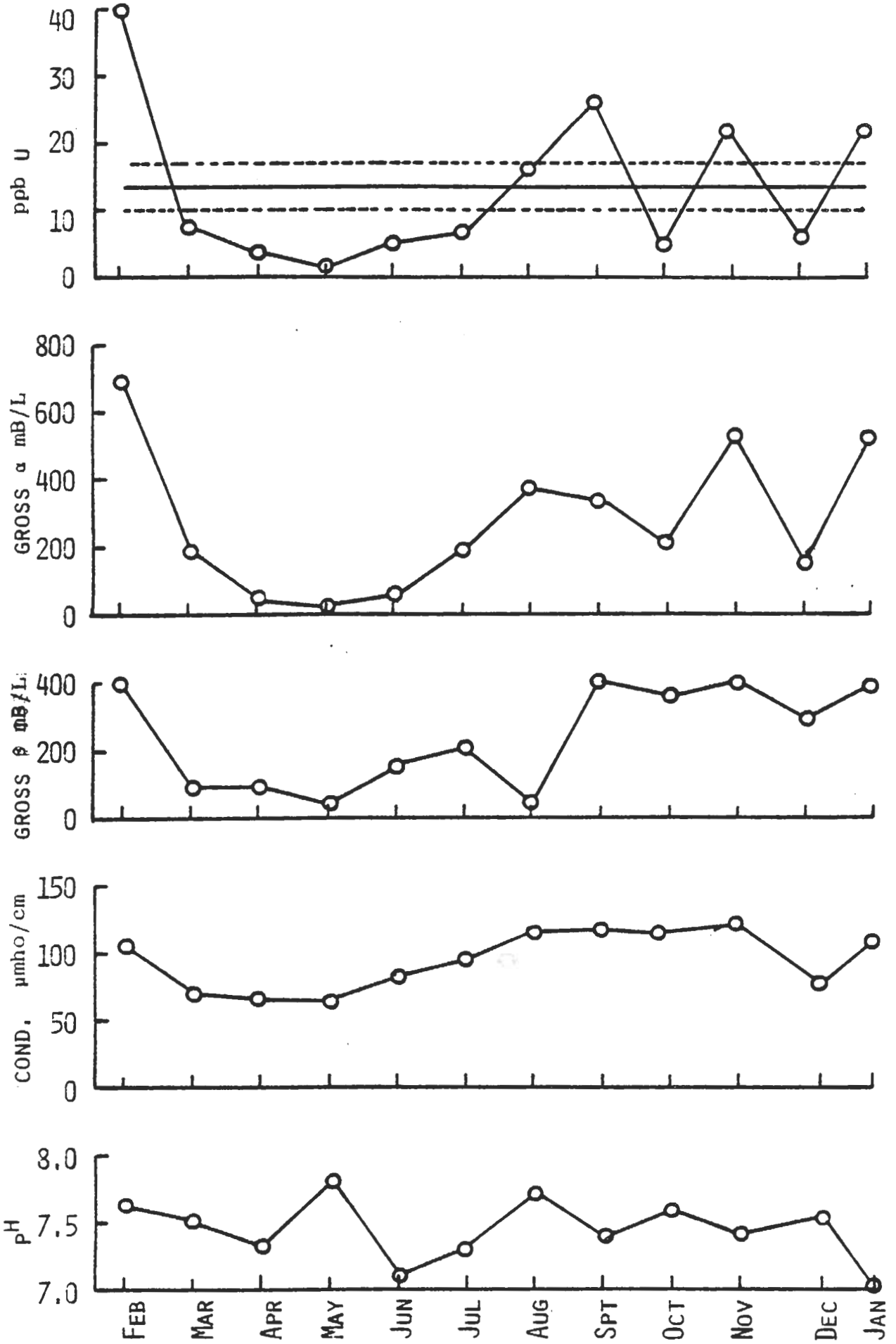


FIG 14 NELSON FOUR MILE CREEK



An interlaboratory comparison of uranium results was made on selected samples taken throughout this study. The data are given in Table 10. The uranium analyses were originally performed at Chemex and then the same samples were submitted to the Ministry of the Environment, Water Resources Laboratory for analysis. The latter lab uses a laser induced fluoresence photometer (Scintrex) to quantify the uranium concentration. They use no sample pretreatment. With the exception of two sets of data which were rejected the agreement between labs is quite good. The correlation coefficient for the two data sets is 0.997. This result indicates a very strong one to one relationship. The major difference in the two sets is a bias factor of approximately 16% of the mean which could be accounted for as a difference in calibration standards.

Considering the above comparison, the precision value given as $\pm$ 10% above 1 ppb is probably a very realistic upper limit.

A sampling variability not exceeding 15% is estimated from the results of Table 11. It should be noted that these are (or should be) samples with low dissolved solids. Samples for which that claim cannot be made could have significantly higher variability. Adding these two variability values for the data given in the above tables gives the range of variability within which one would expect the monthly values to fall if no temporal mechanisms were involved.

These figures demonstrate that only Nelson - Four Mile Creek falls significantly outside the expected maximum sampling and analytical variability. There is, however, another very striking feature of these plots (particularly Figures 9, 10 and 11) and that is their

TABLE 10 Interlaboratory Comparison of Uranium Results

Sample No.	URANIUM (ppb) B.C. Water Resources Laboratory	Chemex
June		
BC 5	0.3	0.25
BR 2	0.4	0.40
KL 4	0.6	0.50
NL 1	5.8	4.0
NL 3	1.2	0.60
NL 5	1.2	0.50
SU 9	1.0	0.70
July		
BC 1	0.2	0.30
KL 4	0.4	0.45
KL 5	0.2	0.55
SU 9	0.9	0.85
August		
BC 3	0.2	0.12
KL 4*	0.2	1.1
KL 5*	0.2	1.1
September		
SU 1	11	7.5
SU 2	22.5	17
SU 3	14	12
SU 4	1.3	0.80
SU 5	1.1	0.92
SU 6	25	18
SU 7	21	15
SU 8	1.5	1.0
SU 9	1.3	0.90
October		
KL 4	0.3	0.15
KL 5	0.3	0.20

* Results rejected as outliers

Table 11. Comparison of monthly composite and grab sample data for tap water.

Area	Site Number	Month	Gross a* (pCi/L)	Gross B* (mBq/L)	Uranium* (ppb)	Conductivity (µmhos/cm)	pH*
Beaverdell	6	March	150±70/< 70	180±100/100±100	9.2/9.2	400/400	7.2/7.9
		April	-	-	6.0/7.0	390/390	7.3/8.0
		May	100±70/< 40	100/ 100	3.5/5.0	400/410	8.1/8.0
	8	May	100±70/220±70	100/220±150	2.9/3.5	420/410	8.0/8.4
Blueberry Creek	3	Feb.	< 40/40±40	100/180±100	0.25/0.30	115/115	7.1/7.1
Hydraulic Lake	3	Feb.	< 40/< 40	100/100	0.30/0.30	-	-
		March	-	-	0.80.0.10	160/145	7.1/7.6
		April	-	-	0.55/0.30	150/145	6.7/7.7
		May	-	-	0.45/0.50	65/69	6.9/7.7
	4	Feb.	< 40/< 40	100/150±100	0.30/0.30	-	-
		March	-	-	0.90/0.10	175/150	7.5/8.0
		April	-	-	0.55/0.30	150/145	6.7/7.9
		May	-	-	0.30/0.40	65/65	6.7/7.7
Nelson	2	Feb.	700±70/590±70	400±100/630	43.0/40.0	105/110	7.6/7.5
		May	-	-	1.2/1.4	65.50	7.8/7.7
	5	Feb.	40±40/< 40	4±3/3±3	2.6/2.7	75.85	7.5/7.4
Summerland	8	Feb.	40/40±40	8±3/5±3	3.7/3.3	170/165	7.2/7.5
		May	-	-	0.55/1.2	70/75	6.9/7.8

* Grab value/composite value

cyclical nature. Certainly one of the major characteristics of both sampling and analytical variability is that it is random in nature. Thus it would seem that although many data points for the Summerland and Beaverdell areas fall within the set variation extremes their cyclical behavior indicates that a temporal mechanism is involved.

In order to gain an impression of the magnitude of shorter term (daily-weekly) compositional changes, data for monthly composite and grab samples from February to May are compared in Table 11. Consistent with the general absence of strong monthly variations, uranium concentrations in these two sample types are very similar. More detailed information on short term variations is available for June and October when weekly composite samples were collected. Analytical results (Table 12) show that weekly changes in uranium concentrations observed under these conditions are relatively small.

"Dissolved" vs "Suspended" Uranium

In addition to routine total determinations, aliquots from a limited number of May grab samples were passed through a 0.7 μm filter and uranium measured in the filtrate. Results of this study are shown in Table 13.

Unfortunately concentrations in many of these samples were low, resulting in relatively poor analytical precision and making interpretation somewhat difficult. Data nevertheless do suggest the existence of significant differences in proportions of "dissolved" and "suspended" uranium in surface water from different areas. Thus in the Nelson sample <50% of the uranium is present in the "dissolved" state, whereas around Summerland up to 100%

TABLE 12 Comparison of Grab and Weekly Composite Uranium, Conductivity and pH Data

Site Number	Grab Sample Date	U (ppb)	Cond. (µmhos/cm)	pH	Weekly Composite Sample Date	U (ppb)	Cond. (µmhos/cm)	pH
Beaverdell					May 28 June 1	5.7	410	8.1
BR 6	June 25	6.8	410	6.4	June 4-8	6.6	400	7.9
					June 11 - 15	7.2	410	6.8
					June 18-22	8.2	405	7.1
Blueberry Creek					June 3-9	0.15	55	7.1
BC 3	June 12	0.15	60	7.3	June 10-16	0.25	65	6.7
					June 17-23	0.25	70	7.1
					June 24-30	0.25	75	7.0
Kelowna					June 4-8	0.50	50	7.4
KL 3	June 18	0.60	50	6.3	June 11-15	1.00	50	7.3
Nelson					Sept. 24-28	5.8	117	7.6
NL 2	Oct. 30	4.6	112	7.6	Oct. 1-5	6.0	117	7.6
					Oct	6.0	118	7.5
NL 2	Dec 20	5.6	75	7.5	Dec. 3-7	26	117	6.9
					Dec. 10-15	16	108	6.7
					Dec. 17-21	11	92	6.9
					Dec 24-28	10	90	6.8
Summerland					June 4-8	1.2	75	7.9
SU 8	June 22	0.55	85	7.3	June 11-15	0.65	85	6.7
					June 18-22	0.70	90	7.0
					June 25-29	0.70	100	7.1
SU 8	Oct 22	1.2	150	7.9	Sept 24-28	0.85	140	7.4
					Oct 1-5	1.00	150	7.1
					Oct 9-12	1.2	150	7.4
					Oct 15-19	1.2	150	7.4
SU 8	Jan 21	2.1	180	7.3	Jan 7-11	1.5	190	7.2
					Jan 14-18	1.8	190	7.2
					Jan 28- Feb 1	1.9	170	7.2

Table 13 Comparison of "dissolved" and "suspended" uranium levels in selected May grab samples*

Area	Site Number	"Dissolved" Uranium		"Suspended" Uranium		Total Uranium
		ppb	% of total	ppb	% of total	ppb
Beaverdell	3	0.20	55	0.15	45	0.35
	4	0.20	80	0.05	20	0.25
	5	0.30	100	0.0	0	0.30
Nelson	1	0.35	30	0.85	70	1.2
	2	0.50	40	0.70	60	1.2
	3	0.15	35	0.30	65	0.45
	4	0.15	45	0.20	55	0.35
Summerland	1	8.3	90	1.1	10	9.4
	3	4.4	75	1.6	25	6.0
	5	0.30	55	0.15	45	0.55
	6**	13.8	95	0.60	5	14.4
	8	0.65	100	-	-	0.55

* Uranium measured by "extraction" method; "suspended" calculated as the difference of total and "dissolved" values; filter size approximately 0.7 µm.

** Well water; other sites represent surface water.

is "dissolved". The Four Mile Creek sample in the Nelson area will be checked to extend this observation to higher uranium levels.

Public Health Considerations

As noted in the Introduction, the proposed Maximum Acceptable Concentration (MAC) for uranium in Canadian drinking water is 20 ppb dissolved uranium. Unacceptably high total uranium levels have been identified in water from Four Mile Creek near Nelson and Eneas and Darke Creeks northeast of Summerland.

Concentrations for Four Mile Creek water for Feb. (up to 43 ppb) were over twice the recommended MAC. Beginning in March, however, values dropped to well within the assumed safe range. The values began to rise again in July. The average 12 month value for this site is 13 ppb.

Uranium levels in Eneas and Darke Creek surface and ground water have been consistently very close to the recommended MAC throughout this study. Well waters are especially pronounced with the 12 month average for Eneas Creek and Darke Creek wells being 19 and 18 ppb respectively. Although it is recognized that the 20 ppb MAC refers to uranium in true solution only, results of the filtration study suggest that a high proportion of the uranium in these anomalous waters is present in the "dissolved" form.

Previous Work

Data from this study are compared with those from the Uranium Reconnaissance Program maps in Table 14. In general there is good agreement between the two data sets.

Table 14 Comparison of uranium values from published Uranium Reconnaissance Program maps and results of this study.

Area	Site Number	Description	Uranium Concentration (ppb)		
			NGR Maps	This Study*	
				Feb.-April	May and June
Beaverdell	1	Trapping Creek	0.90**	1.0 (0.75-1.3)	0.30 (0.15-0.40)
	3	Beaverdell Creek	0.90	1.7 (1.0-2.3)	0.80 (0.35-1.3)
	4	Dear Creek	0.35	0.90 (0.90-0.95)	0.30 (0.25-0.40)
	5	State Creek	0.40	1.4 (1.0-1.9)	0.45 (0.30-0.60)
Blueberry Creek	1	Near Nancy Greene L.	0.10**	0.15 (0.10-0.20)	0.10 (0.05-0.20)
	2	Near municipal intake	0.20**	0.20 (0.15-0.25)	0.20 -
Hydraulic Lake	1	Hydraulic Creek at municipal intake	0.60**	0.35 (0.30-0.45)	0.60 (0.50-0.70)
Nelson	1	Four Mile Creek	3.8	17.0 (3.8-41.0)	2.6 (1.2-4.0)
	3	Duhamel Creek	0.75	2.3 (1.5-2.8)	0.5- (0.45-0.60)
Summerland	1	Garnet L. Spillway	5.3**	12.2 (11.1-14.2)	8.6 (7.8-9.4)
	2	Eneas Creek	13.6	23.6 (22.0-27.0)	17.1 (16.9-17.3)
	3	Darke Creek	4.4	13.9 (12.7-15.6)	7.4 (6.0-8.7)
	4	Trout Creek	0.65	4.7 (3.9-5.9)	0.40 (0.25-0.55)
	5	Trout Creek at intake	0.80	4.8 (3.9-6.7)	0.60 (0.55-0.70)

* Arithmetic mean and true range of values.

** Mean of values for several samples upstream of sampling location for this study.

Thus results of both studies indicate that Beaverdell, Blueberry Creek and Hydraulic Lake-Kelowna area waters typically contain relatively little uranium (0.5-2.0 ppb), whereas those from the Four Mile Creek - Nelson and Summerland areas may be considerably enriched in this element.

Detailed inspection of Table 14, however, reveals that May and June values for this study agree much better with Geological survey data than do the February-April numbers. This situation may in part reflect real seasonal trends in that most of the federal samples were likely collected in the summer months.

GROSS ALPHA ACTIVITY

Geographic and termporal variations in gross alpha levels (Tables 3 - 7) follow those described for uranium. Activities are generally below the detection limits in all but ground water at Beaverdell (40-100 mBq/L), surface water from Four Mile Creek (<40-700 mBq/L) and ground and surface water from Eneas and Darke Creek valleys (<40-590 mBq/L).

Given the relatively low activities observed and the consequent large uncertainties involved in measurement (precision at the 95% confidence level is generally ±30-50% from counting statistics alone), temporal variations in gross alpha levels are characteristically too small to be distinguished. Data for Four Mile Creek however are exceptional in that, as was noted for uranium, activities fall from a high of 700 mBq/L in February to a low of about <40 mBq/L in May and then begin to increase again (Fig. 14).

The apparently close relationship between uranium and gross alpha levels could be, in large measure, directly attributable to the disintegration of uranium itself by alpha emission. Most natural uranium is present as the isotope U-238 which decays to many radioactive daughters one of which is U-234. It can be shown that when these isotopes are in secular equilibrium each microgram of uranium present will contribute 25 mBq of alpha activity or every ppb of U can account for as much as 25 mBq/L of alpha activity. In a number of cases where the Gross α: U ratio exceeded 10 Radium 226 was determined on the sample. The results are listed in Table 14 below.

TABLE 15

Radium-226 Values at Selected Sites

	SITE	Gross α/U	Ra^{226}
NL (1)	Four Mile Creek (Feb.) (Creek sample)	18	26±10 (mBq/L)
NL (2)	Four Mile Creek (Feb.) (Home Composite Sample)	15	22±5
NL (2)	Four Mile Creek (Feb.)	16	18±10
SU (2)	Eneas Creek (Oct.)	19	18±10
SU (2)	Eneas Creek Well (Sept.)	16	< 10
SU (6)	Eneas Creek Well (Oct.)	31	< 10

A linear regression analysis was performed (U conc. vs Gross α) on the sites listed below. With the exception of the Four Mile Creek site it is apparent that the data are too inaccurate to support a multiple regression analysis.

TABLE 16

Linear Regression Analysis of
U Conc. vs Gross α

Site	N(# of values)	Slope	Intercept	Correlation Coefficient
NL 2 (Four Mile Cr.)	9	0.08	-2.8	0.93
SU 1 (Garnet Lk.)	10	0.005	8.37	0.09
SU 2 (Eneas Cr.)	10	-0.03	28	-0.71
SU 3 (Darke Cr.)	9	0.038	6	0.001
SU 6 (well, Eneas Cr.)	10	0	19	0
SU 7 (Well, Darke Cr.)	10	0.03	23	-0.60

Gross α measurement is useful for environmental monitoring only as a preliminary screening technique to evaluate the need for further analysis for specific potentially harmful alpha emitting nuclides. It is apparent from the above results that the predominant α emitter is uranium itself. It would, however, be useful to confirm this conclusion by examining a number of samples high in Gross α by alpha spectroscopy. This should allow the major alpha emitting isotopes to be identified absolutely. These could include isotopes of uranium, thorium and radium.

In Canada the only specific radioisotope to be regulated is Ra^{226}. The (National Health and Welfare, 1978) MAC for Radium 226 in drinking water is 370 mBq/L. None of the values we have measured approach this limit.

FLOW MEASUREMENTS

Flow measurements were not made as a part of the study but data were requested from Water Survey of Canada, Inland Waters Directorate, Pacific and Yukon Region, Environment Canada. Unfortunately most of the

gauging stations of interest to us had been discontinued. The flow data that was received is given in Tables 3 and 5 and one set of data is plotted in Fig. 12. None of the data received is for sites having high uranium levels. Thus a correlation of flow vs uranium concentration was not possible in order to test the dilution effect mechanism which appears to be the most likely explanation of temporal variation.

It would seem imperative to have such flow measurements on Four Mile, Darke, and Eneas Creeks for the second year of monitoring.

V SUMMARY

The results gained to date suggest the following points:

(i) Surface water monitoring techniques: Results of this study suggest that in the areas investigated, at any given time there is generally little difference between uranium and radioactivity levels measured (a) at different points on the same stream, (b) in tap samples obtained from different households on the same water supply, when streams supply local drinking water (c) in water taken from taps and water taken directly from the stream. Thus a great deal of information may be obtained from a single tap sample. Also, over the February-June interval investigated, short term (daily-weekly) temporal compositional variations appear to be slight. Consequently a single grab sample could be nearly as useful for evaluating water quality as a monthly composite.

(ii) Ground water composition: Uranium and radioactivity levels in ground water would appear to be at least equal to and often higher than those for associated surface water. Thus in uranium-rich areas, ground water is of greater public health interest than surface water supplies.

(iii) Reproducibility of URP geochemical map patterns: Within each each trends in uranium distribution observed in this study are consistent with those predicted from URP maps. Furthermore absolute values measured, at least for May and June, are quite similar to those reported in the Federal/Provincial study. These results

therefore suggest that NGR Program maps are accurate representations of compositional variations in surface waters during the summer months.

(iv) Uranium and radioactivity levels in waters around mineralized areas near Hydraulic Lake and north of Beaverdell are at present well within the recommended safe limits. Water from Eneas and Darke Creek valleys north of Summerland and, to a lesser extent, from Four Mile Creek near Nelson is however of some concern since, depending upon the time of sampling, observed uranium concentrations may exceed the 20 ppb MAC. Although gross alpha activities also tend to be high in these uranium-rich samples, radium-226 levels are low.

(v) Alpha radioactivity in all of the samples can be accounted for as activity solely from U^{238} and U^{234}. In support of this contention, Ra^{226} levels in selected samples showed barely detectable levels.

(vi) Only one site showed a significant temporal variation. The other sites show a cyclical variation which strongly indicates that the uranium concentration release to water invoves a temporal mechanism. In either case, the use of only three or four values to determine an average annual intake of uranium and radioactive species could result in an over or under estimate by a significant factor.

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APPENDIX I

Uranium - Radioactivity Monitoring of South Central British Columbia water.- Initial Study Outline

Starting in February, 1979, a program of monitoring (uranium, gross alpha and gross beta) in potable waters from the Okanagan-Kootenay area of British Columbia will be undertaken by Chemex Labs Ltd., on behalf of MMPR. This project will continue through to January, 1980. Field assistance will be provided by the B.C. Ministry of Health (BCMH).

Areas of Study: Seven areas have been tentatively selected for study. Their locations and the approximate number of sample sites proposed for each are as follows:

	Area	No. of Sites
(i)	Kelowna (Hydraulic Lake)	6
(ii)	Birch Island	4
(iii)	Beaverdell	8
(iv)	Summerland	8
(v)	Blueberry Creek	4
(vi)	MacDonald Landing	5
(vii)	Vernon	5
TOTAL		40

The exact positions of sample sites will be decided after consultation with local Ministry of Health personnel later this month.

Sample Collection: Lake, stream, municipal and private well waters will be taken. At each site a sample will be taken by BCMH inspectors at minimum intervals of one month for 12 consecutive months. Additional samples including

"composites", will be obtained periodically at selected sites as a measure of short-term compositional variability. Field personnel will be supplied with details of sample collection procedures to be employed as well as "Field Data Record Forms" to be completed at the time of sampling (see enclosures).

Sample Identification: A sample numbering system similar to that used by the Geochemistry Subdivision of the Geological Survey of Canada will be employed. Samples will be identified by (a) the map sheet number of the National Topographic Series 3" - 4 mi map in which the sample is taken, followed by (b) a two figure number designating the year of sampling, and finally (c) a four figure number identifying the individual sample.

For example: 82F 79 1001
a b c

Each sampling site will be assigned a unique 100 digit series of numbers to be used to identify individual samples for the duration of the project. Thus site #1 could be assigned the series 82F 79 1001 to 82F 79 1100, Site #2 82E 79 1101 to 1200 and so on.

Shipping Logistics: Sample containers and field data record forms will be shipped periodically from Chemex to appropriate BCMH field personnel. As soon as possible after sample collection samples will be sent by the BCMH to Chemex for analysis.

Analyses: All samples collected will be analyzed for total uranium content. In addition beginning in February and if necessary continuing at approximately three month intervals, a subset of the monthly samples will be selected for filtering and measurement of dissolved uranium levels.

In conjunction with the BCMH approximately 30 of the 40 sites being sampled will be chosen for routine gross alpha and gross beta measurement. If gross alpha values approach the 7 pCi/L MAC for radium, a separate radium determination will be made on the samples concerned.

Uranium will be measured fluorometrically down to levels of 0.05 ppb. Analytical quality control will be maintained by inclusion of a "blind" standard with known amounts of uranium in each batch of 20 samples analysed. Radioactivity will be measured using the Canberra 2200 alpha/beta counter. Detection limits of 1 and 10 pCi/L are expected for alpha and beta particles respectively. Accuracy of results on selected samples will be checked periodically by BCMH Laboratories. Precision of measurements will be determined from replicate analyses of laboratory standards.

Data Handling: Field and analytical data will be recorded on appropriate forms (see enclosures) as soon as possible after they are obtained.
Statistical procedures, particularly multiple comparison and Students "t" tests, will be used to examine the significance of:

(i) seasonal compositional variations of each sample site.

(ii) inter-media (ie. stream vs lake vs municipal vs well water) compositional variations within individual sampling areas.

In addition correlation techniques will be employed to examine relationships between data obtained in this study and those reported previously by the Geological Survey of Canada.

Report: A report will be prepared summarizing the results of this study and submitted to
no later than 1980. This report will include sections discussing factors responsible for

compositional variations observed and considering the significance of the data obtained. Recommendations regarding the suitability of this type of program for routine use will be made along with any problem areas which could require further study.

GENERAL GUIDELINES FOR SAMPLE SITE SELECTION

Stream and Lake Water

(i) Sites should be either related to proposed uranium mine developments or municipal drinking water supplies.

(ii) Generally sites should be accessible by road on a year-round basis.

(iii) An attempt should be made to avoid duplication of current monitoring activities being carried out, for example, near the Hydraulic Lake and Blizzard ore deposits.

(iv) An attempt should be made to avoid locating sites near individual point sources of contamination.

(v) If stream water is obtained at road intersections, samples should be collected on the upstream side of roads to minimize possible contamination effects.

Tap Water

Homes with filters, water softeners or other similar devices likely to modify water composition should be avoided if possible.

SAMPLE COLLECTION PROCEDURES

General:

(i) Samples at selected sites should be taken at approximately the same time each month.

(ii) If difficulty is expected in identifying the exact location of stream and lake water sample sites, these should be marked appropriately when the first samples are obtained.

(iii) At the majority of the sites selected, two samples are to be collected in suitably labelled plastic bottles of 250 and 1000 ml. capacities (1000 ml samples will be omitted at about 1/4 of the sites).

(iv) Sample bottles should be rinsed with the water to be collected at least once prior to filling the bottle.

(v) During winter months fill both bottles to 80% of capacity to allow for expansion due to freezing during transportation. Otherwise fill 250 ml bottles to top leaving as little airspace as possible; the 1000 ml bottles should be filled to about 95% of capacity.

(vi) Add 5 ml concentrated HNO_3 to 1000 ml bottles.

(vii) Secure bottle caps firmly.

(viii) Appropriate field forms should be completed at time of sampling for each sample obtained.

Municipal and Well Waters

Allow cold water to run for several minutes before taking samples to remove water standing in pipes.

Stream and Lake Waters

(i) Collect sample in open water as far from shore as possible.

(ii) Avoid disturbing bottom sediment when collecting samples.

APPENDIX II

List of Medical Health Inspectors involved in sample collection

Area	Inspector	Address/Phone
Beaverdell	Wally Ogden	West Kootenay Health Unit 113 SE 10th Street P.O. Box 25 Grand Forks, B.C. 442-8264
Blueberry Creek	Mike Harnadek	West Kootenay Health Unit 1325 McQuarrie Street Trail, B.C. 368-3351
Kelowna-Hydraulic Lake	Bruce Stephen	South Okanagan Health Unit 155 Gray Road Kelowna, B.C. 765-4151
Nelson	Roy Wong	Selkirk Health Unit 385 Baker Street Nelson, B.C. 352-2211; local 334
Summerland	Serg Zibin	South Okanagan Health Unit Kelly Avenue P.O. Box 340 Summerland, B.C. 494-2456