VARIATIONS IN URANIUM AND RADIOACTIVITY LEVELS IN SURFACE AND GROUND WATER AT SELECTED SITES IN BRITISH COLUMBIA April 1980–March 1981

Published by authority of

THE HONOURABLE ROBERT MCCLELLAND

Minister of Energy, Mines and Petroleum Resources

and

THE HONOURABLE JAMES A. NIELSEN

Minister of Health

Victoria, British Columbia
July 1981

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

I INTRODUCTION

This report summarizes field and analytical work carried out between April, 1980 and March, 1981 on a program to investigate uranium and radioactivity levels in potable surface and ground water in selected regions throughout British Columbia. The program was initiated in February, 1979 and a report covering the first year's data has been released (B.C. Ministry of Energy, Mines and Petroleum Resources and B.C. Ministry of Health, 1980). It covered five separate study areas in the Okanagan and West Kootenay regions of south-central British Columbia. For the 1980 - 1981 program, monitoring was continued on sites from three of the above regions to obtain a broader data base. The two other areas (Kelowna - Hydraulic Lake and Blueberry Creek Areas) were dropped from the program since they showed consistent data patterns.

New areas that were added to the program are in the following regions: West Kootenay, South Okanagan, North Okanagan, South Central, Cariboo, Northern Interior and North West (Atlin), British Columbia. The sites are listed and briefly described in Table 1 and the regions are shown in figure 1. More detailed location maps for the South Okanagan and Kootenay regions are given in figures 2, 3 and 4.

The selection of these new sites, as before, was based primarily on initial information giving background uranium concentrations in British Columbia streams. Some sites were selected on the basis of

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)
(2) Nelson (NL)	
	(1) Four Mile Creek
	(2) Four Mile Creek Home (Tap Water)
	(3) Lemon Creek (Hwy. 6 at Bridge)
	(4) Slocan City Supply (Slocan Inn - top)
	(5) New Denver Supply - Village Office
	(6) South Slocan Supply - Post Office
(3) West Kootenay Site (WK)	
	(2) Rock Creek Residence (well)
	(3) Greenwood Water System, W. Kootenay Health Unit
	(4) Midway Water System, Village office
	(5) Grandforks Water System, W. Kootenay Health Unit
	(6) Snowball Creek, near Grand Forks
(4) Beaverdell (BR)	
	(1) Trapping Creek
	(3) Beaverdell Creek
	(4) Dear Creek
	(5) State Creek
	(6) Beaverdell Forestry Office (Municipal well)
	(9) Eugene Creek
(5) Osoyoos	
	(1) Osoyoos Indian Band; T. Alex, McKinny Rd. (well)
	(2) Osoyoos Indian Band; F. Baptiste Res. (well)
(6) Penticton/Oliver (PO)	
	(1) Nkwala Creek
	(2) Shingle Creek, Penticton Indian Reserve
	(3) Indian Rock Residence, Near Naramata (well)
	(5) Keremeos Creek, at bridge on Hwy. 3A
	(6) Tulemeen River, Princeton mun. supply (Sandman Hotel)

AREA SITE

(7) Vernon (VA)

(1) Harris Creek, East of Lumby
(2) Blue Springs Road (well)
(3) Gibson Road, East of Lumby (well)
(4) Kalamalka Lake, Vernon Intake
(5) BX Creek, Vernon Water System
(6) Vernon Residence, Vernon Irregation District
(7) Equesis Creek, Indian Reserve

(8) Armstrong (AR)

(1) Fortune Creek, Silver Star Waterworks
(2) Wyatt Road Residence (well)
(3) Brazier Creek (Stepney Waterworks)

(9) Salmon Arm (SA)

(1) Canoe Creek, South Canoe Elementary School
(2) Shuswap Lake, North Broadview Elementary
(3) Tappen Creek
(4) Syphon Creek, Indian Reserve

(10) South Central Area

(1) Foghorn Creek, Birch Island Water System
(2) Chase Creek at Chase
(3) Merrit Supply, S.C. Health District Office

(11) Williams Lake Area

(1) Williams Lake Supply (well)
(2) 100 Mile House Supply (well)
(3) 108 Ranch (well)
(4) 108 Ranch (well)
(5) Quesnel Supply

(12) Northern Interior Health District

(1) Endako Well, 8 Resident Co-op
(2) B.C. Hydro Substation Well, near Endako
(3) Prince George Supply, College Heights (well)
(4) Prince George Supply, Infiltration Well W.P.#3
(5) Vanderhoof Supply, Artesian Well, $KMnO_4$ Oxidation Pretreatment
(6) Valemont Supply
(7) McBride Supply

(13) Atlin

(1) Pine Creek
(2) Indian Creek
(3) Atlin Lake (Atlin Supply)

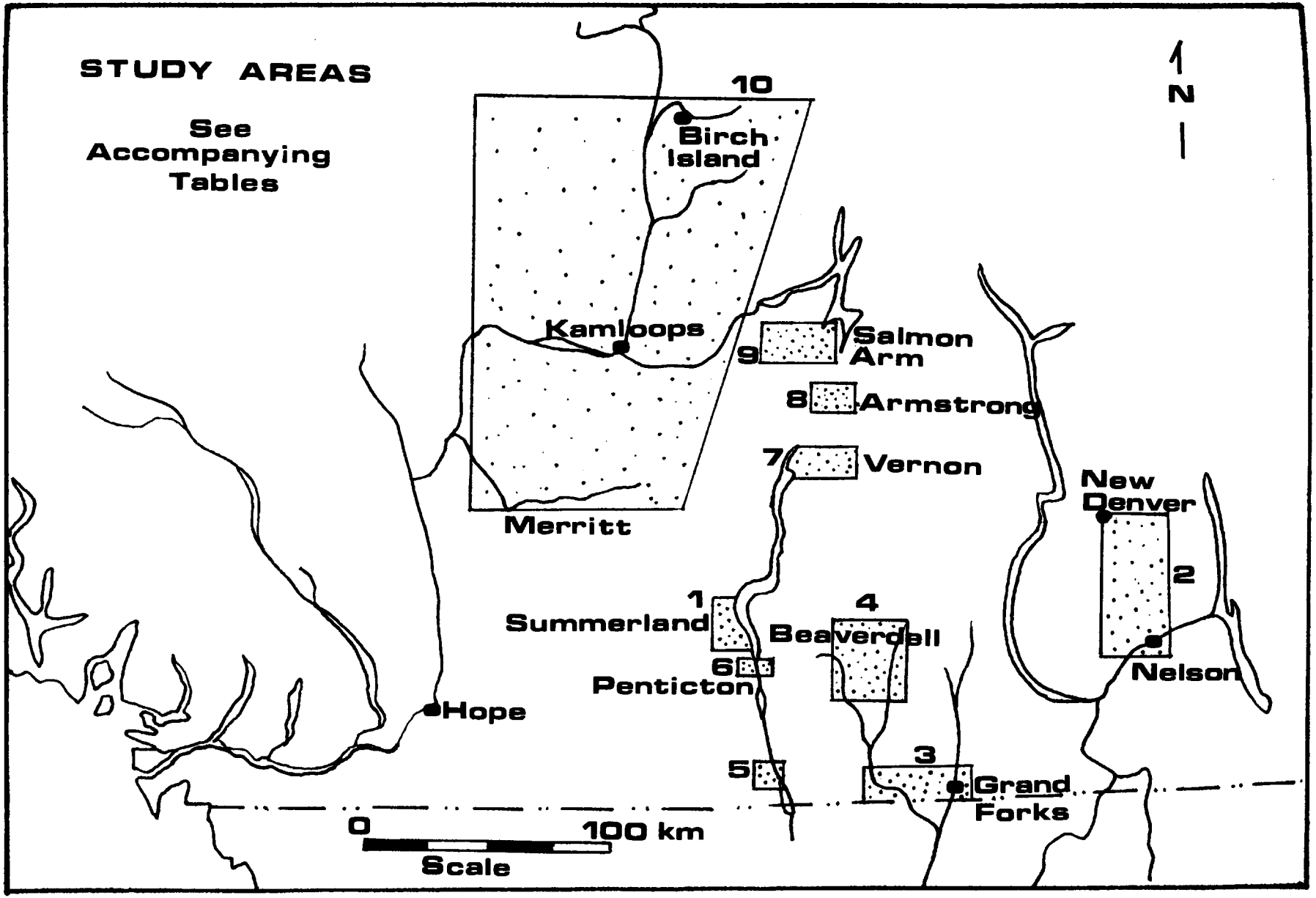

FIG 1: Location of study areas

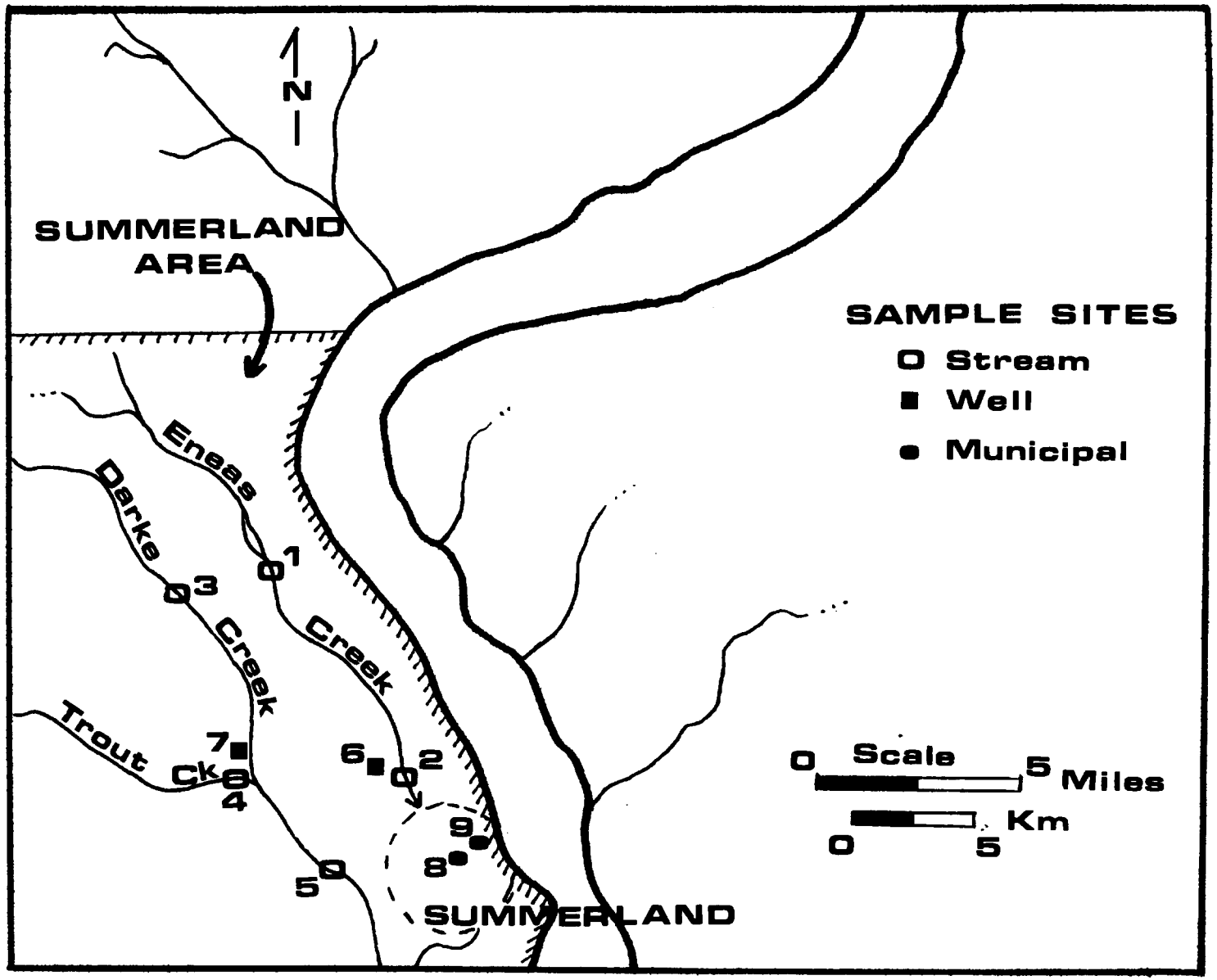

FIG 2: MAP REFERENCE CANADA 82E 2nd Ed., PENTICTON, B.C.

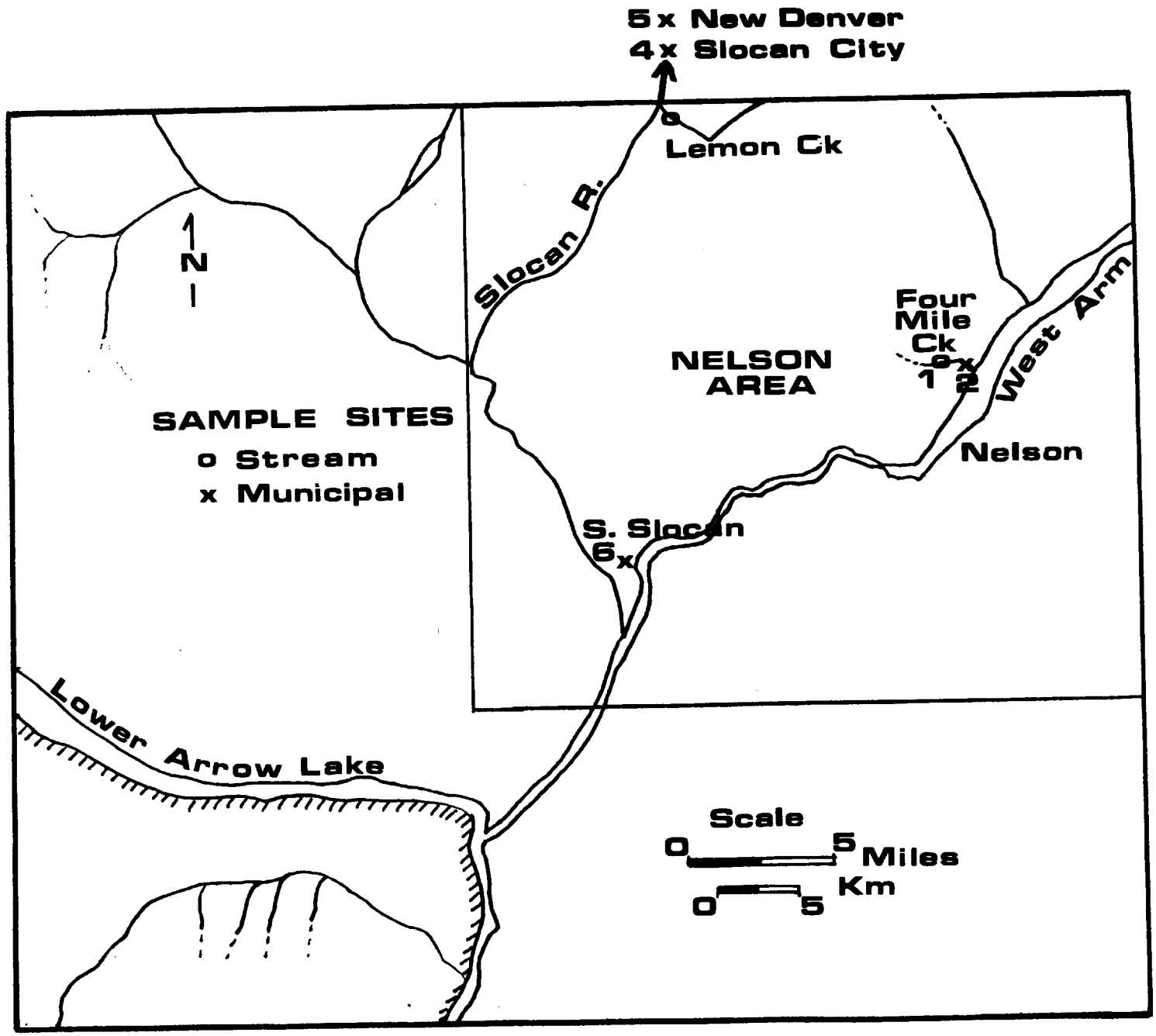

FIG 3: MAP REFERENCE CANADA 82F 2nd Ed., NELSON

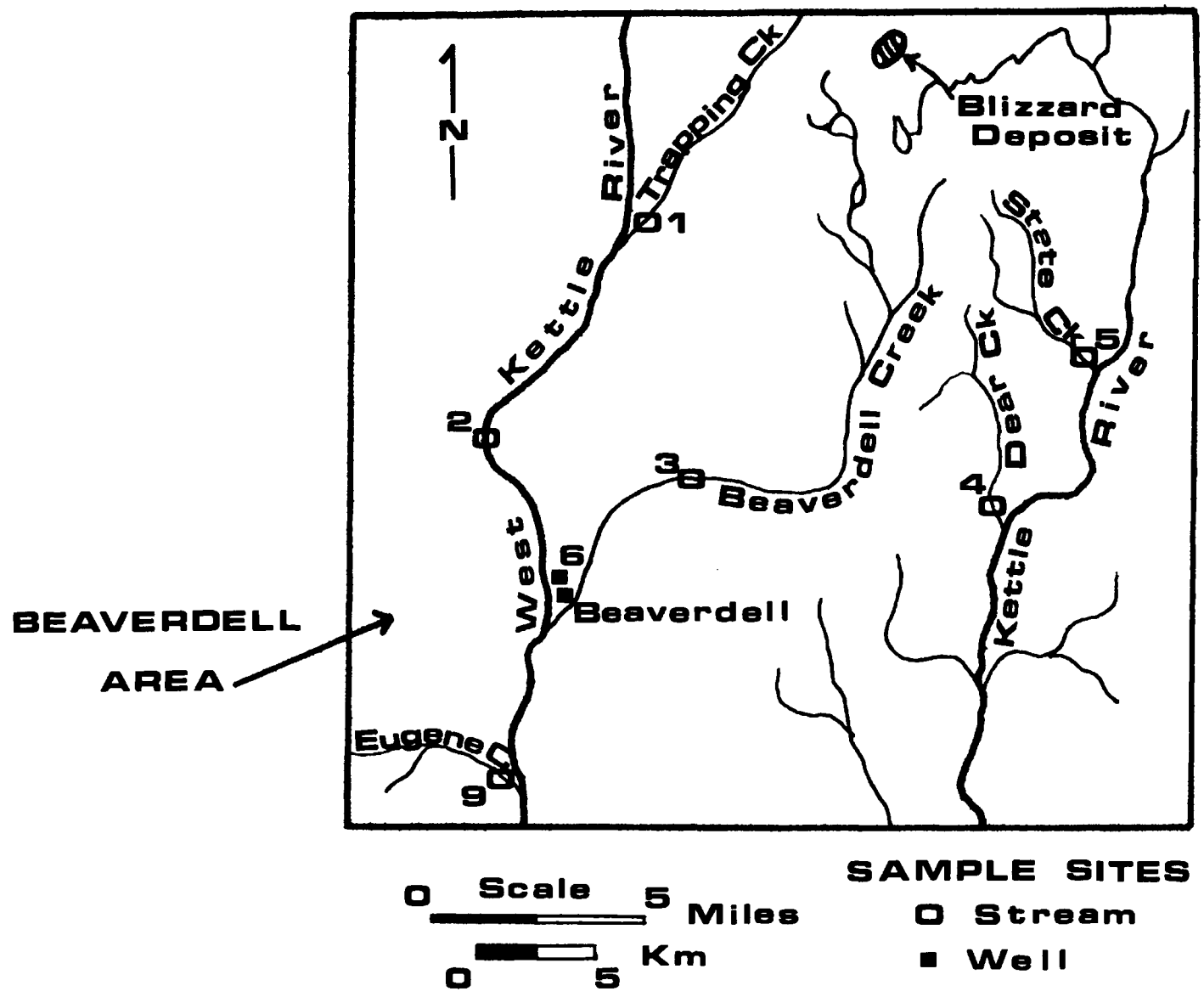

FIG 4: MAP REFERENCE CANADA 82E 2nd Ed., PENTICTON, B.C.

monitoring data supplies by the Radiation Protection Service of the British Columbia Ministry of Health. The source of uranium content in stream waters was the National Geochemical Reconnaissance (NGR) program sponsored jointly by the B.C. Ministry of Energy, Mines and Petroleum Resources and Energy, Mines and Petroleum Resources Canada (1976 and 1977). This geochemical reconnaissance program was further extended solely by the B.C. Ministry of Energy, Mines and Petroleum Resources in 1978, 1979 and 1980 and will continue this year. The areas covered by these programs is shown in figure 5. This map is reproduced from the B.C. Ministry of Energy, Mines and Petroleum Resources Report 'Geological Fieldwork, 1980'.

The work reported here is jointly funded by the B.C. Ministry of Energy, Mines and Petroleum Resources and the B.C. Ministry of Health. The study was coordinated by R.R. Morse, Ph.D. of Chemex Labs in consultation with W.M. Johnson, Ph.D., Chief Analyst, Mines Branch Laboratory, MEMPR and M.W. Greene, Ph.D., Director, Radiation Protection Service, Ministry of Health. In most cases, the samples were collected by Ministry of Health, Public Health Inspectors in each of the areas concerned. The list of inspectors involved in this program is given as Appendix 1. Two additional participants, one from the Atlin area and one from the Osoyoos area, are included in Appendix 1.

The analysis and reported of results were performed by Chemex Labs Limited.

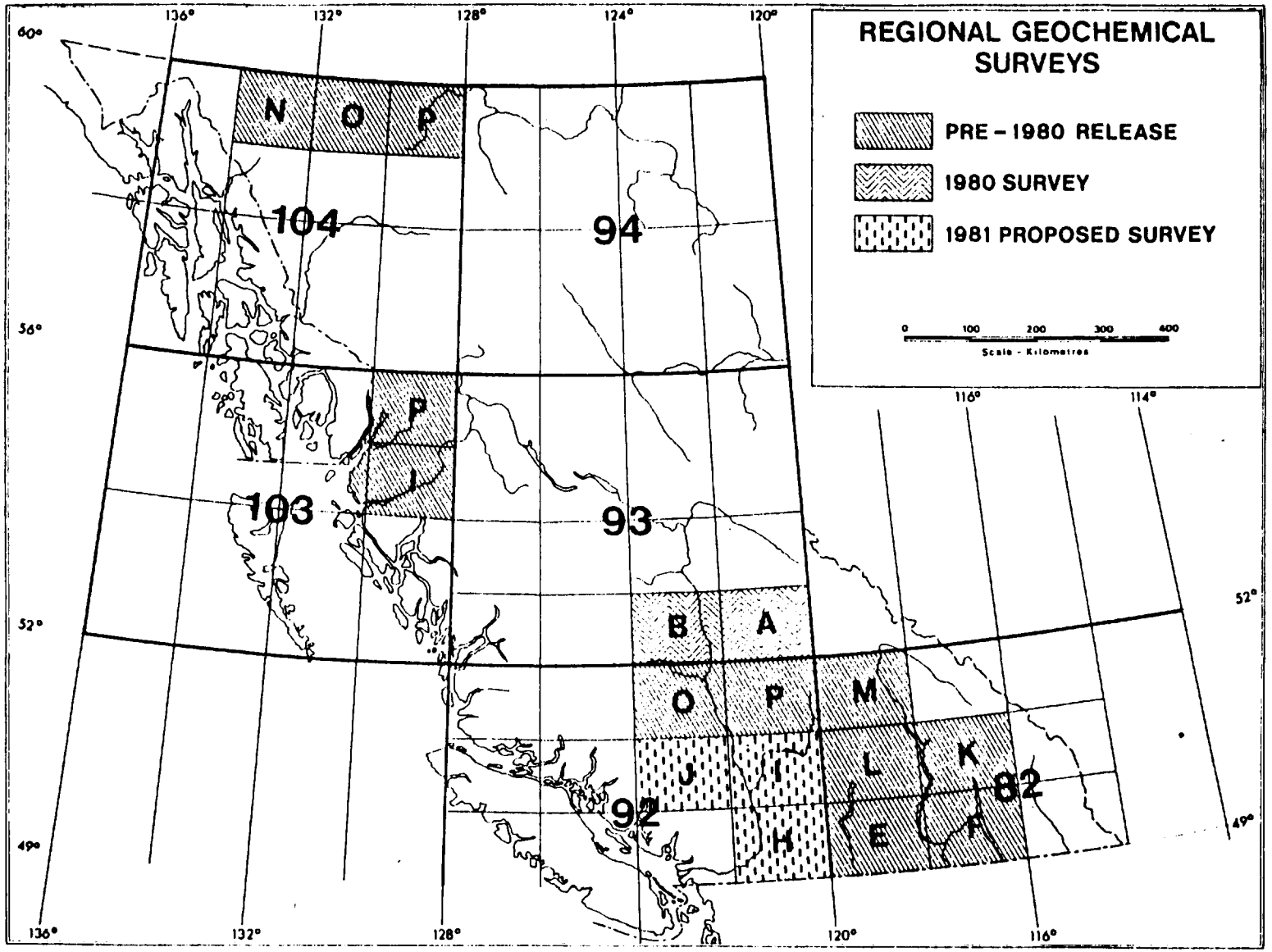

FIGURE 5 REGIONAL GEOCHEMICAL SURVEY WITHIN BRITISH COLUMBIA

II METHODS

SAMPLE COLLECTION AND TREATMENT

Grab samples were collected at one month intervals at each site. Sampling began in April, 1980 and was continued until March, 1981. Samples were collected by local Health Ministry Public Health Inspectors. Names and addresses of individuals involved are given in Appendix 1.

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, one of 250 mL and one of 1 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.

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

ANALYTICAL

Uranium

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

A 50.0 mL aliquot of water is treated with nitric and perchloric acid. The sample is evaporated to dryness and the residue is dissolved in perchloric acid. An aliquot of the resulting solution is transferred to a test tube for extraction of uranium with TPAN (tetrapropylammonium nitrate) in MIBK (methyl isobutyl ketone). A 0.200 mL aliquot of the organic layer containing the extracted uranium is transferred with a micro pipet into a platinum dish and evaporated to dryness. Sodium carbonate/potassium carbonate/sodium fluoride flux is added to the dish and the mixture is fused at 500°C. After cooling, fluorescence of the fused tablet is measured on a Turner Model III fluorometer. The reading is compared to those of standard solutions carried through the same procedure.

This method gives 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 used was 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.

These limits of detection are for the ideal case of samples containing little or no total solids. If total solids of a sample are high a smaller aliquot of sample must be used to minimize self absorption effects.

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 co-precipitation 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 ethylenediaminetetra-acetic acid, barium carrier is added and barium sulfate preferentially precipitated by lowering the pH to 4.5 Radium is coprecipated with the

barium sultate, 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 of allow for the decay of Ra-233 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 Radiometer laboratory model conductivity meter was used. The conductivity measurements are given in μSiemens/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 RESULTS AND DISCUSSION

PHYSICAL SETTING

The geology and mineralization of the areas involved in this study have been described in very general terms in the first report of this series (MEMPR and M. Health, 1980) and in the Royal Commission of Inquiry into Uranium Mining Report (RCUM, Chapter 3, 1980).

ANALYTICAL DATA

The analytical data are reported by area (Table 1) in Tables 2 to 14. Each of these tables contains data on the five paramaters:

(a) uranium content in parts per billion (ppb)

(b) gross Alpha in millibecquerels/litre (mBq/L)

(c) gross Beta in millibecquerels/litre (mBq/L)

(d) conductivity in microSiemens/cm at 25°C (µS/cm)

(e) pH

An equivalent unit for uranium is micrograms per litre (µgm/L). The former conductivity unit, µmhos/cm, is equivalent to µS/cm. The radioactivity unit becquerel can be converted to the more familiar Curie scale using the relationship:

1 picocurie (pCi) = 37 millibecquerels (mBq)

TABLE 2

Area: Summerland

Sites:
1. Garnet Lake Spillway
2. Eneas Creek
3. Darke Creek
4. Trout Creek
5. Trout Creek at Intake
6. Well, Eneas Creek
7. Well, Darke Creek
8. S.O.H.U. Office

	1980										1981		
Uranium (ppb)	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
1	6.5	0.75	3.0	3.2	3.6		3.2	10			1.2	6.2	
2	14	12	9.2	8.6	17	Not Received	18	20	Not Received	Not Received	5.4	14	Not Received
3	11	0.35	2.5	3.6	1.3		7.8	8.5			4.0	8.6	
4	3.4	0.15	0.40	0.50	0.75		1.4	1.8			0.95	2.4	
5	3.2	0.15	0.35	0.55	0.80		1.2	1.7			0.60	2.4	
6		15	9.5	5.8	5.4		1.2	4.8			1.4	6.7	
7	11	12	12	12	18		13	16			0.75	9.4	
8	2.6	0.35	0.30	0.75	0.85		1.0	1.2			0.50	2.2	
Gross α (mBq/ℓ)													
1	120	100	90	<60	80								
2	430	450	230	380	170		280	290			100	210	
3	190	70	70	140	<40		160	110			100	210	
4	140	<40	<40	80	<40								
5	90	60	<40	<40	<40								
6		450	250	250	<70		<40	70			<40	110	
7	230	270	380	330	500		300	230			<40	310	
8	80	80	100	<40	<40								
Gross β (mBq/ℓ)													
1	320	340	290	310	100								
2	220	450	550	300	490		550	570			280	470	
3	400	170	<100	230	230		400	160			130	270	
4	160	210	<100	<100	120								
5	<100	200	120	<100	170								
6		420	710	200	430		<90	160			170	330	
7	470	420	380	250	530		390	350			160	730	
8	160	180	170	100	140								
Conductivity (μS/cm)													
1	360	370	383	388	400		354	334			456	463	
2	500	520	491	464	562		530	484			477	512	
3	320	130	177	204	145		254	262			300	316	
4	180	127	66	77	98		121	122			139	171	
5	170	128	64	76	97		124	122			142	177	
6		660	635	371	365		121	365			422	421	
7	350	365	375	350	372		303	308			161	414	
8	170	160	76	76	105		123	127			158	204	
pH													
1	7.8	7.9	7.7	7.7	7.7		7.6	8.0			7.6	7.7	
2	8.1	8.2	8.1	8.1	8.2		8.0	8.0			8.0	8.0	
3	8.0	7.7	7.8	8.0	8.0		8.0	8.0			8.0	8.0	
4	7.9	7.9	7.5	7.8	8.0		8.0	7.9			7.8	7.8	
5	7.9	7.9	7.5	7.4	8.0		7.9	7.8			7.8	7.8	
6		7.3	7.3	7.5	7.7		7.9	7.7			7.5	7.8	
7	8.1	7.9	7.3	7.7	7.8		7.7	8.0			7.5	7.8	
8	7.5	7.6	7.5	7.7	7.7		7.7	7.6			7.4	7.6	

TABLE 3

Area: Nelson

Sites:
1. Four Mile Cr. (Above Intake)
2. Four Mile Cr. Home
3. Slocan Valley - Lemon Creek
4. Slocan Valley - Slocan City (Mun.)
5. New Denver Supply
6. South Slocan (Well)

				1980						1981	
Uranium (ppb)	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
1				4.4	8.3	14	26	11	3.6	5.0	12	2.4
2 (Charcoal filter)			1.8	5.0	8.6	14(13)	25	10	3.8	5.2	8.8	2.7
3			0.3	1.7	1.2	1.1	2.3	1.3	1.3	0.55	2.6	2.5
4			0.5	0.25	0.05	<0.05	0.55	<0.5	0.20	0.05	0.25	0.15
5			0.35	0.40	0.50	0.40	0.60	0.50	0.50	0.25	0.75	0.60
6			0.90	1.3	4.5	0.75	1.1	0.65	2.7	2.0	4.2	0.85
Composites Wk 1				2.7	5.2	9.5	18					
2				4.4	5.7	9.7	17					
3				4.1	5.4	11						
4					7.4	14						
						14						
Gross α (mBq/ℓ)												
1				80	160	320	420	280	110	250	230	90
2			80	70	180	190(200)	280	270	110	220	230	100
3			<40	<40	50							
4			<40	<40	<40							
5			<40	<40	60							
6			<40	<40	90							
Composites Wk 1				50	110	230	340					
NL 2 2				210	140	210	280					
3				70	140	110						
4					220	290						
						240						
Gross β (mBq/ℓ)												
1				130	550	280	420	3370	180	220	180	140
2			<100	210	<120	180(410)	440	2610	<100	380	340	140
3			<100	<100	130							
4			<100	<100	270							
5			<100	130	140							
6			<100	<100	280							
Composites Wk 1				130	<110	350	470					
NL 2 2				250	250	410	530					
3				<100	260	420						
4					<120	340						
						140						
Conductivity (μS/cm)												
1			63	80	104	96	102	88	59	85	86	57
2			42	80	100	91(102)	102	92	58	95	89	57
3			13	48	72	62	72	74	61	97	85	76
4			215	13	26	22	82	34	26	84	37	76
5			73	217	219	205	200	190	176	216	199	185
6				83	94	100	108	104	73	38	92	29
Composites Wk 1				67	88	92	105					
NL 2 2				77	92	97	101					
3				75	97	88						
4					99	91						
						94						
pH												
1				7.6	7.7	7.4	7.8	7.6	8.5	7.0	7.4	7.4
2			7.4	7.6	7.7	7.7(7.8)	7.8	7.6	7.7	7.3	7.4	7.4
3			7.4	7.6	7.8	7.7	7.7	7.6	7.8	7.4	7.5	7.7
4			6.8	7.0	7.2	7.0	7.8	7.3	7.4	7.5	7.2	7.3
5			7.9	7.8	7.8	7.8	7.9	7.8	7.9	7.3	7.7	7.6
6			7.5	7.8	7.7	7.8	7.9	7.6	7.5	7.5	7.8	7.7
Composites Wk 1				7.4	7.6	7.5	7.9					
NL 2 2				7.6	7.6	7.6	7.8					
3				7.5	7.8	7.7						
4					7.8	7.7						
						7.8						

TABLE 4

Area: West Kootenay
Sites:
2. Rock Cr. (Well)
3. Greenwood Mun. Supply (Well)
4. Midway Mun. Supply
5. Grand Forks Mun. Supply
6. Grand Forks Snowball Creek

			1980							1981	
Uranium (ppb)	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
2			3.3	1.5	1.6	2.4	3.0		2.6	2.4	1.9	2.0
3			1.6	0.6	0.60	0.80	0.95		0.50	0.75	0.65	0.75
4			4.2	2.8	3.2	4.8	6.3		4.8	4.2		4.4
5			3.2	1.8	1.6	2.5	3.8		2.4	2.4	2.3	2.6
6				0.35	0.95	0.70	2.2		1.3	1.1	1.0	1.0
Gross α (mBq/ℓ)												
2			<50	<40	<80							
3			<40	<40	<50							
4			160	<60	80							
5			<80	40	<90							
6				<40	<50							
Gross β (mBq/ℓ)												
2			140	150	<110							
3			<100	<100	<110							
4			250	150	240							
5			<100	100	<120							
6				<100	<120							
Conductivity (μS/cm)												
2			310	310	304	286	291		359	310	330	308
3			240	255	209	226	240		237	255	267	259
4			390	350	350	352	376		378	414		418
5			380	330	345	366	355		360	380	400	398
6				183	227	183	207		187	163	163	147
pH												
2			7.8	7.8	7.8	7.7	7.8		8.0	7.7	7.6	7.0
3			6.7	7.0	6.8	6.9	7.0		7.1	6.8	6.9	6.3
4			8.0	8.0	7.9	7.8	8.0		8.0	7.9		7.3
5			8.0	8.0	8.0	7.8	8.1		8.1	7.9	7.7	6.5
6				7.7	7.5	7.6	7.6		7.3	7.6	7.6	7.2

TABLE 5

Area: Beaverdell
Sites: 1. Trapping Creek, 3. Beaverdell Creek, 4. Dear Creek, 5. State Creek, 6. Beaverdell Ranger Station

					1980						1981	
Uranium (ppb)	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
1	0.45	0.20	0.20	0.20	0.20	0.70		0.10	0.10	0.40	0.30	0.75
3	0.40	0.35	0.50	0.45	0.95	2.1		1.2	1.5	1.0	1.1	0.75
4	0.20	0.20	0.35	0.30	0.40	0.75		0.55	0.60	0.70	0.55	0.55
5	0.25	0.15	0.45	0.55	0.45	0.70		0.50	0.65	0.55	0.70	0.55
6	5.6	4.0	5.8	5.5	6.4	6.6		5.6	6.2	5.3	5.5	5.2
9			5.7	4.2	5.6	7.2		7.2				6.6
Gross α (mBq/ℓ)												
1	<40	<40			<40							
3	40	<40			<40							
4	<40	<40			<40							
5	<40	<40			<40							
6	80	190			170							
9			150	90	120							
Gross β (mBq/ℓ)												
1	170	240			120							
3	<100	230			240							
4	<100	100			<120							
5	<100	110			<120							
6	<120	100			140							
9			170	140	<130							
Conductivity (μS/cm)												
1	30	23	42	40	44	56		47	53	45	50	57
3	87	112	140	170	200	226		210	221	195	171	133
4	101	123	150	165	179	198		188	196	196	174	140
5	96	108	150	163	193	223		201	211	201	202	140
6	410	410	370	390	366	336		364	389	422	428	405
9			230	235	238	304		299				248
pH												
1	6.8	7.0	7.8	6.5	7.4	7.5		7.5	7.5	7.3	7.2	7.0
3	7.5	7.9	8.0	7.4	8.1	8.1		8.0	8.0	7.9	7.4	7.3
4	7.6	8.0	8.1	7.4	8.0	8.0		8.1	8.0	8.0	7.5	7.4
5	7.7	7.9	8.1	7.4	8.2	8.2		8.1	8.1	8.0	7.8	7.4
6	7.2	7.8	7.2	6.6	7.0	7.2		7.1	7.2	7.5	7.0	6.6
9			8.1	7.5	8.2	7.2		8.2				7.2

TABLE 6

Area: Osoyoos

Sites:	1. Indian Reserve (Thomas Alex, McKinny Rd.)							2. Indian Reserve (Fred Baptiste)				
					1980						1981	
Uranium (ppb)	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
1						9.3	13					12
2						31	40					33
3												
4												
Gross α (mBq/ℓ)												
1						260	260					320
2						640	1000					510
3												
4												
Gross β (mBq/ℓ)												
1						600	360					400
2						560	1750					760
3												
4												
Conductivity (μS/cm)												
1						242	250					249
2						635	650					572
3												
4												
pH												
1						7.4	7.3					7.4
2						8.0	7.9					7.6
3												
4												

TABLE 7

Area: Penticton/Oliver

Sites:
1. Nkwala Cr.
2. Shingle Cr. (Penticton, Indian Reserve)
3. Indian Rock, Res.
5. Keremeos Cr.
6. Tulumeen R., Princeton

				1980						1981		
Uranium (ppb)	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
1				8.4	16	11		128		25	31	21
2				3.0	4.2	4.0		5.2		5.1	3.3	4.8
3				2.2	2.0	2.2	2.6	1.8		2.3	2.0	2.0
5				0.20	0.20	0.10		0.35		0.30	0.50	
6				0.70	0.20	0.05		0.10		0.25	0.35	
Gross α (mBq/ℓ)												
1 (Ra-226)				100	<160	<160		1350(30)		440(15)	530	540
2				190	<140	<100		140		140	<90	140
3				<40								
5				<40								
6				<40								
Gross β (mBq/ℓ)												
1				610	400	990		1030		1310	1200	1020
2				280	<140	400		<190		<190	<200	320
3				<350								
5				140								
6				100								
Conductivity (μS/cm)												
1				660	725	758		1000		1070	801	695
2				370	620	378		350		309	293	337
3				1400	540	1100	1100	1080		1170	1213	1320
5				180	203	201		225		221	246	
6				160	155	114		165		172	158	
pH												
1				9.8	9.0	8.5		8.0		7.4	7.4	7.4
2				7.3	7.4	7.2		8.1		7.8	8.0	8.2
3				7.5	7.5	7.4	7.4	7.4		7.4	7.2	7.2
5				7.8	7.8	7.8		8.0		7.7	7.8	
6				8.0	8.0	7.9		7.4		7.2	7.6	

TABLE 8

Area: Vernon
Sites:

1. Harris Cr. (E. of Lumby)
2. Blue Springs Rd. (Well)
3. Gibsons Rd. (Well)
4. Kal Lk. (Vernon Intake)
5. Bx Cr. (Vernon Intake)
6. Vernon Irrigation Dist. (House)
7. Equesis Cr. (Indian Res.)

			1980							1981	
Uranium (ppb)	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
1			0.15	0.15	0.75	0.40	0.30	0.15	0.35	0.65	1.2	
2			6.4	4.2	4.8	5.0	5.6	5.5	5.2	6.0	6.2	7.6
3			5.2	3.0	4.7	4.5	5.0	4.5	3.3	4.5	4.4	4.5
4			2.0	1.4	2.0	1.6	1.8	1.6	1.1	1.8	1.8	2.0
5			0.50	0.30	0.65	0.50	0.45	0.60	0.60	0.75	0.70	
6			0.25	0.15	1.9	0.15	0.05	0.10	0.15	0.30	0.25	
7			0.25	0.15	0.25	0.30	0.10	0.15	0.10	0.30	0.50	
Gross α (mBq/ℓ)												
1			<40	<40	<70							
2			140	<100	490							
3			<70	70	<120							
4			120	120	200							
5			50	<40	200							
6			<40	<40	250							
7			<40	<40	50							
Gross β (mBq/ℓ)												
1			130	<100	150							
2			700	440	400							
3			400	<190	730							
4			380	400	290							
5			220	110	360							
6			120	150	480							
7			140	<100	260							
Conductivity (μS/cm)												
1			47	110	265	72	203	156	270	280	303	
2			870	780	850	715	535	710	874	848	808	870
3			560	560	540	450	498	542	576	570	440	556
4			380	370	376	521	326	355	389	390	418	400
5			140	210	283	196	224	232	261	230	249	
6			120	120	370	74	72	84	90	96	101	
7			69	100	175	163	139	174	205	170	186	
pH												
1			7.3	7.6	7.7	7.3	7.9	7.7	7.7	7.8	7.3	
2			7.3	7.2	7.3	7.2	7.4	7.6	7.4	7.4	7.4	7.2
3			7.2	7.8	7.2	7.1	7.5	7.6	7.4	7.7	7.3	7.2
4			8.2	8.2	8.5	8.3	8.6	8.5	8.3	8.1	8.0	8.1
5			7.8	7.8	8.2	7.3	8.2	8.2	8.1	8.0	7.7	
6			7.5	7.3	8.5	6.9	7.7	7.0	7.1	7.8	7.1	
7			7.6	7.8	8.1	8.1	8.1	7.8	8.1	8.0	7.7	

TABLE 9

Area: Armstrong Area
Sites: 1. Fortune Creek (Silver Star Wtr-wks) 2. Wyatt Rd. (Well) 3. Brazier Creek (Stepney Wtr-wks)

			1980								1981	
Uranium (ppb)	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
1			0.25	0.50	1.1	0.45	0.60	0.55	0.35	0.95	1.0	
2			14	9.7	13	12	16	14	12	13	16	21
3			0.15	0.25	0.30	0.40	0.30	0.10	0.25	0.30	0.55	
Gross α (mBq/ℓ)												
1			<40	<40	60							
2			130	390	430	<220	450	<260	360	690	<230	390
3			<40	40	60							
Gross β (mBq/ℓ)												
1			<100	<100	<100							
2			1270	1730	1160	610	970	<460	825	1200	<450	1150
3			<100	140	240							
Conductivity (μS/cm)												
1			120	160	210	182	186	183	208	198	199	
2			1300	1200	1220	1200	922	960	1087	1031	1078	1292
3			57	170	72	76	80	70	154	59	86	
pH												
1			7.5	7.8	8.0	8.0	8.0	8.0	7.9	7.8	7.5	
2			7.3	7.2	7.1	7.4	7.4	7.5	7.4	7.4	7.4	7.4
3			7.6	7.4	7.4	7.7	7.6	7.7	7.8	7.4	7.6	

TABLE 10

Area: Salmon Arm
Sites:
1. Canoe Creek (Salmon Arm Supply)
2. Salmon Arm Office
3. Tappen Creek
4. Syphon Creek (Indian Reserve)

			1980							1981	
Uranium (ppb)	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
1			0.25	0.30	0.40	0.30	0.25	0.35	0.25	0.45	0.55	
2			0.25	0.20	0.95	0.10	0.20	0.10	0.05	0.35	0.05	
3			2.2	1.3	1.8	2.4	2.0	2.0	2.2	2.2	2.2	2.4
4			3.0	4.5	10	14	17	13	17	14	12	11
Gross α (mBq/ℓ)												
1			160	350	350	<50	<50	<50	<50	<50	<70	
2			60	150	150					<50		
3			120	<40	<40					<50		
4			40	220	220	200	180	247	250	90	660	220
Gross β (mBq/ℓ)												
1			530	360	360	<120	140	1100	1100	320	<110	
2			420	230	230					<100		
3			140	240	240					560		
4			200	260	260	410	340	120	120	290	560	340
Conductivity (μS/cm)												
1			290	330	340	290	240	102	275	332	358	
2			110	108	120	94	75	275	102	98	108	
3			360	353	350	315	240	340	280	329	358	379
4			130	202	280	260	210	300	245	246	402	267
pH												
1			8.3	8.2	8.1	8.2	8.3	7.9	8.2	8.4	8.1	
2			7.2	7.7	7.8	7.8	7.8	8.4	7.8	7.8	7.8	
3			8.4	8.3	8.3	8.3	8.4	8.3	8.3	8.2	8.2	8.2
4			8.0	8.1	8.1	8.1	8.2	8.1	8.1	8.0	7.9	8.0

TABLE 11

Area: South Central Area

Sites: 1. Foghorn Creek - Birch Island 2. Chase Creek (Mun. Supply) 3. Merritt (Mun. Supply)

					1980						1981	
Uranium (ppb)	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
1		0.40	0.55	2.5	1.4	2.0	1.4	2.2	3.0	3.6	2.9	4.4
2		0.35	0.15	0.40	0.50	0.35	0.35	0.35		0.70		
3		0.15	0.20	0.30	0.20	0.20	0.15	0.15	0.40	0.70	0.65	
Gross α (mBq/ℓ)												
1		<60	<40	50	<60							
2		100	<40	<40	<40							
3		60	<40	<50	<40							
Gross β (mBq/ℓ)												
1		1410	<100	100	<120							
2		360	180	145	150							
3		340	<100	<100	140							
Conductivity (μS/cm)												
1		114	150	197	234	186	214	251	325	182	363	403
2		76	93	165	191	113	165	156		286	-	
3		212	230	234	216	179	235	240	295	328	260	
pH												
1		7.8	7.9	8.2	8.2	8.0	8.2	8.1	8.1	7.4	8.1	8.3
2		7.6	7.8	7.9	8.2	7.9	8.2	8.0		7.1	-	
3		7.3	7.0	7.3	7.0	7.2	7.4	7.2	7.2	8.1	7.4	

TABLE 12

Area: Williams Lake

Sites:
1. Williams Lk Supply (Wells)
2. 100 Mile House (Wells)
3. 108 Ranch (Well)
4. 108 Ranch (Well)
5. Quesnel Supply

				1980						1981	
Uranium (ppb)	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
1				0.75	0.45	0.9						
2				2.8	2.2	3.0						
3				0.35	2.6	3.1						
4				3.8	0.50	0.35						
5				0.10	0.45	0.10						
Gross α (mβq/ℓ)												
1				<120	<140	<140						
2				<130	<130	<130						
3				<220	260	<320						
4				330	<200	<190						
5				<40	<40	<40						
Gross β (mβq/ℓ)												
1				<380	<300	<390						
2				<360	<340	720						
3				700	920	<460						
4				<400	<400	<400						
5				<100	<100	210						
Conductivity (μS/cm)												
1				815	840	690						
2				930	1040	805						
3				1150	1330	1400						
4				1275	1250	1250						
5				194	260	195						
pH												
1				7.8	7.9	7.9						
2				7.9	7.8	7.8						
3				7.1	7.6	7.9						
4				7.5	7.0	7.5						
5				8.1	8.0	8.1						

TABLE 13

Area: Prince George

Sites:
1. Endako Supply (Well)
2. B.C. Hydro Endako Substation (Well)
3. P.G. Supply (Well)
4. P.G. Supply (Well)
5. Vanderhoof Supply (Well)
6. Valemont
7. McBride

				1980						1981		
Uranium (ppb)	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
1				9.2		9.9		12		4.2		
2				54		64		68		46		
3		0.15	0.55	0.95	0.50	0.50	0.75		0.40	0.70	0.75	0.95
4		0.50	0.10	0.25	0.20	0.10	0.10		0.20	0.30	0.30	0.25
5 (Before treatment)				6.4		2.9(5.8)	11	6.0(5.9)		2.8	5.8(5.6)	
6		0.15	0.15	0.10	0.40	0.25	0.35		0.35	0.55	0.90	0.85
7		1.1	0.15	0.25	0.15	0.15	0.20	0.05	0.20	0.25	0.25	0.40
Gross α (mBq/ℓ)												
1				180		110		220		<130		
2(Duplicate)				760		850		760		1000(1210)		
3		<50	<40	<50	<40							
4		80	<40	<40	<40							
5				80								
6		<40	<40	<40	<40							
7		<40	40	<40	<40							
Gross β (mBq/ℓ)												
1				330		540		<190		<220		
2(Duplicate)				900		1150		500		<210(1000)		
3		<100	110	120	140							
4		310	<100	300	<100							
5				600								
6		<100	<100	<100	<100							
7		<100	200	<100	<100							
Conductivity (μS/cm)												
1				445		454		445		480		
2				423	260	428		660		502		
3		84	260	250	200	255	205		288	280	294	235
4		86	220	210		155	100		235	223	228	171
5 (Before treatment)				621	360	650(638)	670	680(680)		758	690(676)	
6		200	62	85	290	105	82		141	128	157	138
7		290	56	75		90	145	500	107	103	109	96
pH												
1				7.7		7.6		7.8		7.6		
2				8.0	7.7	7.8		7.7		7.7		
3		7.3	7.7	8.6	7.2	7.7	7.4		7.8	7.8	7.3	7.8
4		7.8	7.3	7.5		7.3	8.1		7.6	7.4	7.0	7.3
5 (Before treatment)				7.8	8.4	7.7(7.7)	7.9	7.8(7.8)		7.7	7.6(7.6)	
6		7.6	8.2	8.4	7.8	8.1	7.7		8.6	8.1	7.7	8.4
7		8.3	7.7	7.9		7.7	7.3	7.5	7.8	7.7	7.5	7.8
Ra-226 (mBq/ℓ)												
1				<7								
2				33						22		
3												
4												
5				18								
6												
7												

TABLE 14

Area: Atlin
Sites: 1. Pine Creek 2. Indian Creek 3. Atlin Lake (Supply)

			1980							1981	
Uranium (ppb)	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
1			0.50	1.4	1.3	1.4		1.1				
2			2.6	7.4	8.2	11		6.8				
3			0.30	0.45	0.40			0.30				
Gross α (mBq/ℓ)												
1			60	290	90	<70		<40				
2			70	190	<40	310		140				
3			230	130	<40			<40				
Gross β (mBq/ℓ)												
1			290	400	350	290		<100				
2			440	360	<100	<160		2070				
3			150	<130	<100			500				
Conductivity (μS/cm)												
1					113	89		121				
2					310	221		297				
3					105			104				
pH												
1					8.2	7.7		7.9				
2					7.8	7.8		7.8				
3					7.9			7.9				

Occasionally an additional sample was taken at one particular time and site. Where feasible the additional value is placed in brackets beside the regular value and a brief description of the value is given in brackets near the sample number.

It should be noted that none of the tables is complete with respect to the number of parameters analysed or the number of months for which samples were taken.

In most cases the parameters omitted were gross alpha and beta determinations. These two are expensive determinations which are of questionable value at or near their detection limits. Thus it was decided to limit these analyses to selected sites that showed any significant values within the first three months of the study or to sites that showed relatively high uranium values. Samples from sites that did not meet either of these two criteria were not analysed for radioactivity on a blanket coverage basis. If, however, a sample from any site contained 10 ppb uranium or more the sample was also analysed for radioactivity.

The gaps in the sampling frequency of the various regions were caused by a number of factors including inaccessibility to the sites in winter months and limited resources within the Health Units to handle this additional sampling load.

Table 15 is a summary table of all of the data by parameter and site. The headings are as follows:

TABLE 15

MEANS, STANDARD DEVIATIONS, AND EXTREMES

	n	Uranium (ppb) $\bar{x}$±1 S.D.	Min	Max	Gross α (mBq/ℓ) $\bar{x}$±1 S.D.	Min	Max	Gross β (mBq/ℓ) $\bar{x}$±1 S.D.	Min	Max	Conductance (μS/cm) $\bar{x}$±1 S.D.	Min	Max	pH $\bar{x}$±1 S.D.	Min	Max
Summerland Area																
1. Garnet Lk. Spillway	9	4.2±2.9	0.75	10							390±44	334	463	7.7±0.1	7.6	8.1
2. Eneas Cr.	9	13±4.8	5.4	20	280±120	100	450	420±160	<220	570	504±30	464	562	8.1±0.1	8.0	8.2
3. Darke Cr.	9	5.3±3.8	0.35	11	120±60	<40	210	230±120	<100	400	234±73	130	320	7.9±0.1	7.7	8.0
4. Trout Cr.	9	1.3±1.1	0.15	3.4							122±38	66	180	7.8±0.2	7.5	8.0
5. Trout Cr. at Intake	9	1.2±1.0	0.15	3.2							122±38	64	177	7.8±0.2	7.4	8.0
6. Well, Eneas Cr.	8	6.2±4.4	1.2	15	150±150	<40	450	300±220	< 90	710	420±160	121	660	7.6±0.2	7.3	7.9
7. Well, Darke Cr.	9	12±5	0.75	18	285±130	<40	500	410±160	160	730	333±73	161	414	7.8±0.2	7.3	8.1
8. S.O.H.U. Office	9	1.1±0.8	0.30	2.6							133±43	76	204	7.6±0.1	7.4	7.7
Nelson Area																
1. Four Mile Cr. (Above Intake)	9	9.6±7.3	3.6	26	210±110	80	420	610±1045	130	3370	84±17	57	104	7.6±0.4	7.0	8.5
2. Four Mile Cr. Home	10	8.5±7.3	1.8	25	170±80	80	280	450±770	<100	2610	83±17	57	102	7.6±0.2	7.3	7.8
3. Slocan Valley - Lemon Cr.	10	1.5±0.8	0.3	2.6							69±16	42	97	7.6±0.1	7.4	7.8
4. Slocan Valley - Slocan City	10	0.16±0.16	<0.05	0.55							54±28	13	84	7.2±0.3	6.8	7.2
5. New Denver Supply	10	0.48±0.14	0.35	0.75							187±57	176	219	7.8±0.2	7.3	7.9
6. S. Slocan (Well)	10	1.9±1.4	0.75	4.5							79±27	29	108	7.7±0.1	7.5	7.9
Beaverdell Area																
1. Trapping Cr.	11	0.33±0.22	0.10	0.75							44±10	23	56	7.2±0.4	6.8	7.8
3. Beaverdell Cr.	11	0.94±0.53	0.35	2.1							170±46	87	221	7.8±0.3	7.3	8.1
4. Dear Cr.	11	0.47±0.19	0.20	0.75							165±32	101	198	7.8±0.3	7.4	8.1
5. State Cr.	11	0.50±0.17	0.15	0.70							172±43	96	223	7.9±0.3	7.4	8.2
6. Beaverdell Ranger Stn.	11	5.6±0.70	4.0	6.2							390±28	336	428	7.1±0.3	6.6	7.8
7. Eugene Cr.	6	6.6±1.7	4.2	7.2							259±33	230	304	7.7±0.5	7.2	8.2
W. Kootenay Area																
2. Rock Cr. (Well)	9	2.3±0.6	1.5	3.3							312±22	286	330	7.7±0.3	7.0	8.0
3. Greenwood (Mun. Well)	9	0.8±0.3	0.6	1.6							243±18	209	267	6.8±0.2	6.3	7.1
4. Midway (Mun. Sup.)	8	4.3±1.0	2.8	4.8							378±27	350	418	7.9±0.2	7.3	8.0
5. Grand Forks (Mun.)	9	2.5±0.7	1.6	3.2							268±23	330	400	7.8±0.5	6.5	8.0
6. Snowball Cr.	8	1.1±0.5	0.35	2.2							182±26	147	227	7.5±0.2	7.2	7.7

TABLE 15 (Cont'd)

MEANS, STANDARD DEVIATIONS, AND EXTREMES

		Uranium (ppb)			Gross α (mBq/ℓ)			Gross β (mBq/ℓ)			Conductance (μ S/cm)			pH		
	n	$\bar{x}$±1 S.D.	Min	Max	$\bar{x}$±1S.D.	Min	Max	$\bar{x}$±1 S.D.	Min	Max	$\bar{x}$±1 S.D.	Min	Max	$\bar{x}$±1 S.D.	Min	Max
Penticton/Oliver Area																
1. Nkwala Cr.	7	34±42	8.4	128	520±450	100	1350	940±320	400	1310	816±158	695	1070	8.2±0.9	7.4	9.8
2. Shingle Cr.	7	4.2±0.9	3.0	5.2							380±110	293	620	7.7±0.4	7.2	8.2
3. Indian Rock (Res.)	8	2.1±0.2	1.8	2.6							1115±258	540	1400	7.4±0.1	7.2	7.5
5. Keremeos Cr.	6	0.28±0.14	0.10	0.50							212±23	180	246	7.8±0.1	7.7	8.0
6. Tulumeen R.	6	0.28±0.23	0.05	0.70							154±20	114	172	7.7±0.3	7.2	8.0
Vernon Area																
1. Harris Cr.	9	0.45±0.35	0.15	1.2							190±97	47	303	7.6±0.2	7.3	7.9
2. Blue Springs Rd.	10	5.6±1.0	4.2	7.6							786±107	535	874	7.3±0.1	7.2	7.6
3. Gibsons Rd.	10	4.4±0.7	3.0	5.0							530±49	440	576	7.4±0.2	7.1	7.8
4. Kal Lk.	10	1.7±0.3	1.1	2.0							392±52	370	521	8.3±0.2	8.0	8.6
5. Bx Cr.	9	0.56±0.14	0.30	0.75							225±41	140	261	7.9±0.3	7.3	8.2
6. Vernon Irr. Dist.	9	0.37±0.58	0.05	1.9							125±93	72	370	7.4±0.5	6.9	8.5
7. Equesis Cr.	9	0.23±0.13	0.10	0.50							153±43	69	205	7.9±0.2	7.6	8.1
Armstrong Area																
1. Fortune Cr.	9	0.64±0.30	0.25	1.1							183±28	120	210	7.8±0.2	7.5	8.0
2. Wyatt Rd. (Well)	10	14±3.1	9.7	16	320±200	130	690	940±475	<460	1730	1130±130	922	1300	7.4±0.1	7.1	7.5
3. Brazier Cr.	9	0.29±0.13	0.10	0.55							92±41	57	154	7.6±0.1	7.4	7.8
Salmon Arm Area																
1. Canoe Cr.	9	0.34±0.10	0.25	0.55				460±390	140	1100	284±78	102	358	8.2±0.1	7.9	8.4
2. Salmon Arm Office	9	0.25±0.28	0.05	0.95							121±59	75	275	7.8±0.3	7.2	8.4
3. Tappen Cr.	10	2.1±0.3	1.3	2.4							330±42	240	379	8.3±0.1	8.2	8.4
4. Syphon Cr.	10	12±5	3.0	17	230±160	40	250	290±130	120	560	250±70	130	402	8.1±0.1	7.9	8.2
South Central Area																
1. Foghorn Cr.	11	2.2±1.2	0.40	4.4							238±90	114	325	8.0±0.2	7.4	8.3
2. Chase Cr.	8	0.36±0.16	0.15	0.70							156±66	76	286	7.8±0.4	7.1	8.2
3. Merrit Supply	10	0.31±0.20	0.15	0.70							243±42	179	328	7.3±0.3	7.0	8.1

TABLE 15 (Cont'd)

MEANS, STANDARD DEVIATIONS, AND EXTREMES

	n	Uranium (ppb) $\bar{x}$±1 S.D.	Min	Max	Gross α (mBq/ℓ) $\bar{x}$±1 S.D.	Min	Max	Gross β (mBq/ℓ) $\bar{x}$±1 S.D.	Min	Max	Conductance (µS/cm) $\bar{x}$±1 S.D.	Min	Max	pH $\bar{x}$±1 S.D.	Min	Max
Prince George Area																
1. Endako (Well)	4	8.8±3.3	4.2	12	140±70	<130	220				456±16	445	480	7.7±0.1	7.6	7.8
2. B.C. Hydro Sub Stn.	4	58±10	46	68	842±110	760	1000	660±460	<210	1150	455±145	260	660	7.8±0.1	7.7	8.0
3. P.G. Supply (Well)	10	0.62±0.25	0.15	0.95							235±62	84	294	7.7±0.4	7.3	8.6
4. P.G. Supply (Well)	10	0.23±0.12	0.10	0.50							181±56	86	228	7.5±0.3	7.0	8.1
5. Vanderhoof Supply	6	5.8±3.0	2.8	11							633±130	360	758	7.8±0.3	7.6	8.4
6. Valemont (Supply)	10	0.40±0.28	0.10	0.90							139±67	62	200	8.1±0.3	7.6	8.6
7. McBride (Supply)	11	0.29±0.28	0.05	1.1							157±137	56	500	7.7±0.3	7.3	8.3
Atlin Area																
1. Pine Cr.	5	1.1±0.4	0.5	1.4							110±20	89	121	7.9±0.2	7.7	8.2
2. Indian Cr.	5	7.2±3.0	2.6	11	140±110	< 40	310				276±48	221	310	7.8 -	7.8	7.8
3. Atlin Lk.	4	0.36±0.1	0.30	0.45												

n is the number of months a site was sampled.

$\bar{x}$ is the average parameter value for the n determinations.

$\pm$ 1 S.D. is one standard deviation from the mean.

Min Max are the extreme minimum and maximum respectively values for the parameter over n determinations.

Tabulations for the Williams Lake Area and the Osoyoos Area were not included in this table due to a lack of sufficient data.

In the following section some comments on the data by region are given. Before doing this, however, the background uranium values by region as determined by the Federal/Provincial Uranium Reconnaissance Program and subsequent Provincial Regional Geochemical Surveys (Figure 2) are given as well as the Federal guidelines for Canadian Drinking Water Quality.

The regional background levels of uranium in stream water are all below 1 ppb uranium and in most cases the levels are well below this value. These regional background levels are determined from several hundreds of samples representing uniform coverage of the area [see for example Geological Survey of Canada Open File 517, 1977 (Atlin), Open Files 409, 410, 411, 1976 (Vernon, Summerland, Grand Forks, etc.)].

The Federal Health and Welfare (1978) guidelines for drinking water quality with respect to the parameters analysed in this program are as follows:

pH - An acceptable range for drinking water pH is from 6.5 to 8.5

TABLE 16

URANIUM CONCENTRATION RATIOS

GROUND/ASSOCIATED SURFACE WATER

Beaverdell

Site	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
Well													
6/3 Beaverdell Creek		14	11	12	12	6.7	3.1		4.7	4.1	5.3	5.0	7.4

Summerland

Site												
Well												
6/2 Eneas Creek		1.2	1.0	0.67	0.32		0.06	0.24			.26	.48
7/3 Darke Creek	1.0	34.	4.8	3.3	14		1.7	1.9			.19	1.1

Uranium - A maximum acceptable concentration of 0.02 mg/L (20 ppb) for uranium in drinking water has been established based on considerations of the chemical toxicity of uranium.
The objective concentration for uranium is less than or equal to 0.001 mg/L (1 ppb).

Radium 226 - The maximum acceptable concentration of radium-226 is 1 becquerel per liter (Bq/L) and the target concentration of 0.1 Bq/L.

Gross α and Gross β - Gross α and gross β radioactivity determinations are only suitable as preliminary screening procedures. Compliance with the guidelines may be inferred, however, if the measurements for gross alpha and gross beta activity are less than the most stringent target concentrations, 0.1 and 1.0 Bq/L, the guidelines for radium-226 and strontium 90, respectively.

Summerland Area (Table 2)

In the Summerland Area both surface and ground water in Eneas and Darke Creeks are characterized, as they were the year before, by relatively stable, elevated uranium values, and measureable though low radioactivity levels.

Table 16 gives the ratios of groundwater uranium content and associated surface water uranium content for both Eneas Creek and Darke Creek.

The surface water of Eneas Creek shows a two to three fold increase in uranium content over the 10 km distance between Site 1 (Garnet Lake Spillway) and Site 2 in Eneas Creek.

Trout Creek, Trout Creek at Intake and South Okanagan Health Unit Office samples all have similar uranium contents over each sampling period.

Nelson Area (Table 3)

The Four Mile Creek site was maintained from the previous year's program. Although the overall mean values of the uranium and radioactivity content of the Four Mile Creek samples were somewhat lower than last year there were still very significant fluctuations from month to month. Some weekly composite samples were taken at Four Mile Creek. The results of these composite samples showed good agreement with the monthly 'grab' sample.

The kitchen tap of the household that supplied the tap sample at Four Mile Creek was fitted with a Water Pic charcoal filter. Results before and after the charcoal filter are shown for July. There appears to be little effect on uranyl ion removal from this type of filter. At the end of the four month trial period the charcoal filter cartridge was removed and the contents were analysed for total uranium content. The results indicated that 68 micrograms of uranium were retained within the filter over that period. It is likely that the retained uranium was part of the particulate matter trapped by the filter.

The rest of the samples, from the Slocan Valley, showed stable and low values throughout the study period.

West Kootenay Area (Table 4)

Most of the sites within this area were municipal water supplies (wells). They all have stable values over the entire sampling period.

Beaverdell Area (Table 5)

Well water from site 6 (Beaverdell Ranger Station) and surface water from site 9 (Eugene Creek) have somewhat elevated uranium levels with respect to the other sites in this region.

The ratio of uranium content in ground to associated surface water near Beaverdell is given in Table 16. The ratios indicate a higher proportion of ground to surface water content as they did in the previous year's program.

Osoyoos Area (Table 6)

Only three sets of samples were obtained from this area which is located on the property of the Osoyoos Indian Band. The two shallow wells sampled showed elevated levels of uranium and radioacitivity. One site (site 2 - Fred Baptiste well) had levels of uranium higher than the MAC guidelines of 20 ppb on all three samples taken.

Penticton Oliver Area (Table 7)

All of the sample sites for this region are surface samples. Nkwala Creek has significantly elevated levels of uranium and radioactivity. This creek, however, drains a small pond which appears to be similar to the alkaline ponds described by Culbert et al. The average value for uranium at site 1 exceeds the MAC guidelines for drinking water.

Shingle Creek and Indian Rock Residence have stable though slightly elevated uranium levels.

Vernon Area (Table 8)

All of the sites sampled over the 10 month period showed stable values throughout. The two ground water sites Blue Springs Road and Gibsons Road wells have values that are two to three time greater than surrounding surface water.

Armstrong Area (Table 9)

Wyatt Road well has consistently elevated uranium and radioactivity values. It is a very shallow well (6 meters) which effectively utilizes surface drainage.

Salmon Arm Area (Table 10)

Three of the four sites samples showed stable values throughout the study period. The Canoe Creek and municipal residence sites were consistently low in both uranium and radioactivity. Tappen Creek was slightly elevated in uranium. Syphon Creek on Indian Reserve number 6 showed a seasonal variation in uranium ranging from 3 ppb in June to 17 ppb in December.

South Central Area (Table 11)

Foghorn Creek at Birch Island had uranium values that ranged over a factor of 10 to 0.4 ppb in May to 4.4 ppb in March. The other two sites Chase Creek supply and Merritt supply had low stable uranium contents throughout the monitoring period.

Williams Lake Area (Table 12)

Only data for the summer months were available.

Prince George Area

This region covers a considerable territory. Most of the sites sampled are municipal supplies. The two Prince George infiltration wells have stable low values of uranium and negligible radioactivity.

(Sites 3 and 4) as do the supplies for Valemont and McBride (Sites 6 and 7).

The Vanderhoof supply is a deep artesian well. It has somewhat elevated uranium contents that range over approximately a factor of three throughout the sampling period.

Several times during this monitoring period samples were taken before the artesian water was treated with potassium permanganate primarily to remove ferrous and manganese ions. The results are inconclusive as to whether the permanganate treatment has any effect on removing uranyl ions.

The Endako co-op supply well has consistently elevated levels of uranium that vary by a factor of three over the sampling period.

The B.C. Hydro Endako Substation well has high uranium and radioactivity values which are relatively stable throughout the entire monitoring program. The mean uranium concentration for this site is more than double the MAC guideline value.

Atlin Area

Pine Creek and Atlin Lake show stable uranium values and negligible radioactivity.

Indian Creek uranium values are slightly elevated and range over a factor of three from 2 - 6 ppb in June to 11 ppb in September.

IV SUMMARY

The results gained to date, ie. those found in this report and those given in the earlier report (MEMPR and M. Health, 1980), suggest the following points:

(i) Surface water monitoring techniques: Results of the earlier study suggested that in the area 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 and (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, 1979 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. As a result of this feature only a very limited number of composite samples were collected in the second year of the program. Also tap water samples were used extensively.

(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 NGR Program map patterns: within each area trends in uranium distribution observed in this study are consistent with those predicted from Geological Survey of Canada (1976 and 1977) maps and the British Columbia Ministry of Energy, Mines and Petroleum Resources Regional Geochemical Survey data 1979. Furthermore absolute values measured, at least for May and June, are quite similar to those given in the reconnaisance geochemical reports. 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 most 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 involves 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

List of Public Health Inspectors involved in sample collection

Area	Inspector	Address/Phone
Summerland	Stan Husch	South Okanagan Health Unit P.O. Box 340 Summerland, B.C. 494-2456
Nelson	Roy Wong	Selkirk Health Unit 385 Baker Street Nelson, B.C. 352-2211 Loc. 334
West Kootenay Beaverdell	Wally Ogden	West Kootenay Health Unit 113 S.E. 10th Street P.O. Box 25 Grand Forks, B.C. 442-8264
Osoyoos	Rita Gallagher (Band Health Representative)	Osoyoos Indian Band P.O. Box 340 Oliver, B.C. V0H 1T0 498-3444
Penticton/ Oliver	Jim Shannon	South Okanagan Health Unit 300 Eckart Avenue, E. Penticton, B.C. 492-6116
Vernon	Norman Gallant	North Okanagan Health Unit 3300 - 37th Avenue Vernon, B.C. 545-0651
Armstrong	Peter Jemmeson	North Okanagan Health Unit 3300 - 37th Avenue Vernon, B.C. 545-0651

Area	Inspector	Address/Phone
Salmon Arm	Pat O'Neill	North Okanagan Health Unit Salmon Arm, B.C. 832-2147
Indian Reserves within the Vernon Area	Denis Wahoski	Health and Welfare Canada Environmental Officer Salmon Arm, B.C. 832-6185
South Central	Wayne Watts	South Central Health Unit Chase, B.C. 679-3737
	Ken Christian	South Central Health Unit 519 Columbia Street Kamloops, B.C. 372-5212
Williams Lake	Fred Ainley	Cariboo Health Unit 113 - 4th Avenue, N. Williams Lake, B.C. 392-4484
Prince George	John Jarvis	Northern Interior Health District 1444 Edmonton Street Prince George, B.C. 563-1631
	Serg Zibin	Northern Interior Health District Vanderhoof, B.C. 567-4721
	Denise Hutchinson	Northern Interior Health District P.O. Box 301 Burns Lake, B.C. 692-3171
Atlin	Ed Johnstone (Government Agent)	Government Agent Third Street Box 100 Atlin, B.C. 651-7577