CHAPTER 16

Sub-Basin Groundwater Reconnaissance Studies

16.1 HYDROGEOLOGY OF VASEUX CREEK SUB-BASIN

Vaseux Creek (Fig. 16.1) includes a drainage area of some 97 square miles above a gauging station situated at a point about 5 miles upstream from the mouth of the creek where it joins Okanagan River. Vaseux Creek drainage basin rises to elevations of more than 6,500 feet and more than 75 square miles lies above an elevation of 4,500 feet. Vaseux Creek is the trunk stream for 5 major tributaries.

16.1.1 Geology

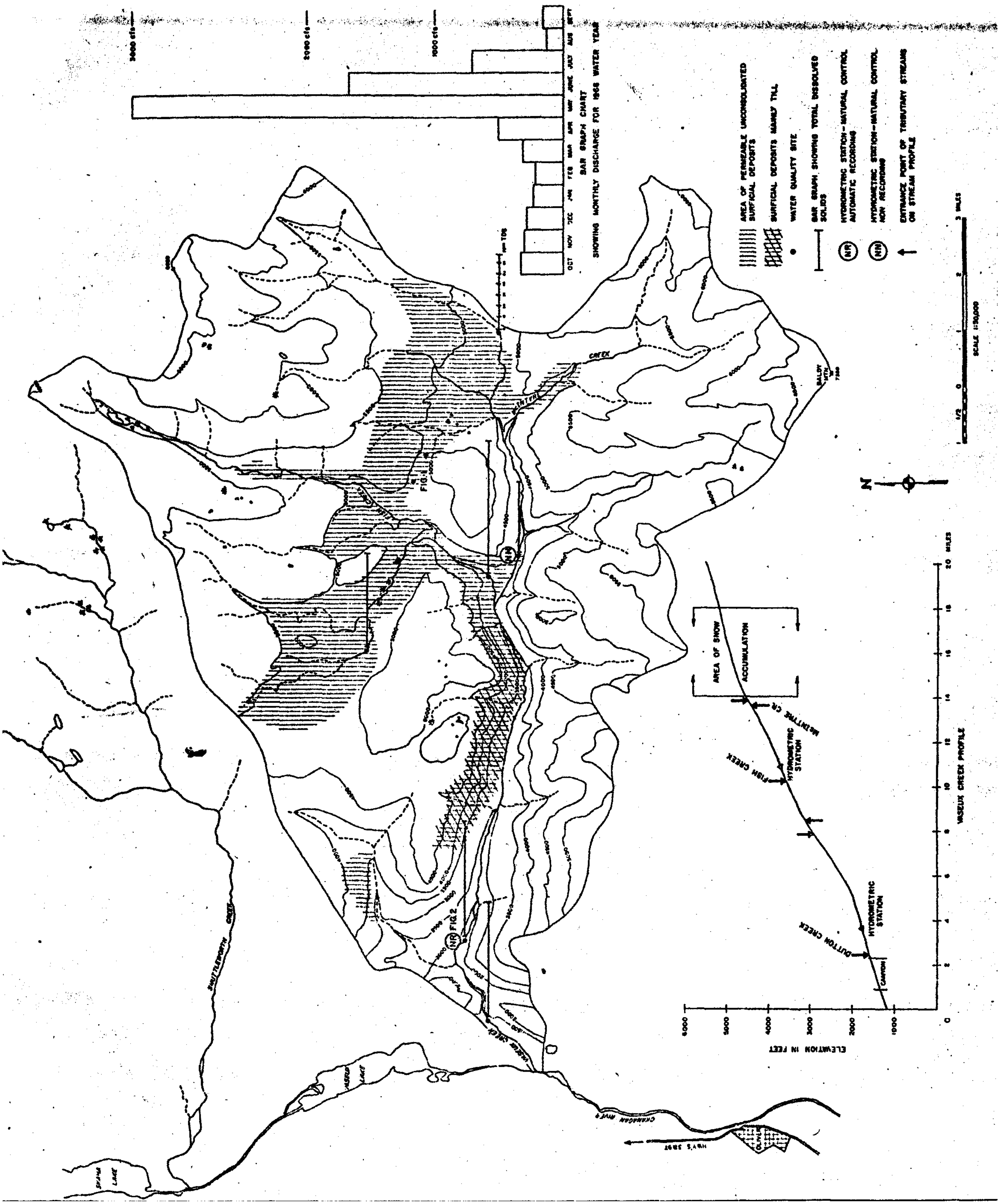
Vaseux Creek drainage basin is underlain by the Shuswap terrane that comprises a group of metamorphic rocks but younger intrusive granitic and granodiorite rocks are exposed at the surface over much of the area. During Pleistocene time the area was ice covered and erosion of the bedrock, in particular. The granitic rocks provided material for the deposition of grey silty stony, clay and till and meltwaters left ice-contact and outwash gravel and sand to form extensive areas of surficial deposits within the plateau-like uplands between elevations of 4,000 and 5,000 feet (see map, distribution of surficial deposits). These surficial deposits not only provide a soil (Photo 16.1) for the stands of timber covering the area but also provide a medium for the storage and movement of groundwater contributed by snowmen seepage.

16.1.2 Hydrology

No climatological stations or snow courses exist in the basin. A gauging station on Vaseux Creek, at an elevation of about 1,500 feet, has been in operation since 1958 providing continuous records (Photo 16.2). A bar graph chart shows the runoff (see map) for the 1966 water year and its monthly distribution. The 1966 water year was below normal but the graph illustrates the distribution of the discharge which reaches a peak in May following the near disappearance of the season's snowmelt.

The study of groundwater flow systems in crystalline rocks under a similar geological environment was undertaken by D.W. Lawson* in the Trapping Creek drainage basin tributary to the West Kettle River and about 20 miles northeast of Vaseux Creek basin. The quantitative flow net for that basin depicts local flow systems superimposed on an intermediate flow system that in turn overlies a regional flow system. Lawson concluded that flow through the combined regional and intermediate flow system that in turn overlies a regional flow system.

* Lawson, D.W., Groundwater flow systems in the crystalline rocks of the Okanagan Highland, British Columbia, Canadian Journal of Earth Sciences, Volume 5, 1968.



VASEUX CREEK DRAINAGE BASIN

Figure 16.1

Photo 16.1 Vaseux Creek Drainage Basin, unconsolidated surficial deposits with stand of lodgepole pine

Photo 16.2 Hydrometric Station, Vaseux Creek

Lawson concluded that flow through the combined regional and intermediate flow systems is at most less than 2 percent of the flow through the local flow systems and the local flow system adjacent to the creek supports the groundwater component of baseflow. In Trapping Creek the local flow systems in the crystalline rock complex contributes from 10 to 17 imperial gallons a day per foot thickness of aquifer. In the Vaseux Creek basin a local flow system exists in the permeable surficial deposits and the intermediate and regional flow systems are confined to the massive bedrock in which flow is negligible and hence these systems can be discounted as providing any significant volume water to the overall regime. The local flow systems during the 1967 water year contributed a baseflow in the order of 3 cfs during the months of August and September and it is assumed that discharge during those months was entirely groundwater. Groundwater discharge at this rate during the year provided a little more than 10.5 percent of the total discharge of 43,110 acre feet.

Water samples were collected from 7 points in the basin to assess by geochemical means any groundwater contributions to the creek discharge. The chemical analyses are presented in Table 16.1 and bar diagrams on the accompanying map show the total of dissolved solids at sampling points. Discharge from the Fish Creek tributary has the highest concentration of total dissolved solids and this represents groundwater discharge that had been stored in the unconsolidated deposits primarily of a granitic provenance hence the higher concentration of the cations calcium, magnesium, sodium, and potassium. The samples collected on Vaseux Creek below the entrance of McIntyre Creek have a lesser concentration of cations because the discharge from this creek is in part snowmelt and surface runoff from Baldy Mountain which rises to an elevation of more than 6,500 feet at the drainage divide. The sample, taken at the gauging station where discharge at the time of sampling was in the order of 3.0 cfs shows the result of mixing of Fish Creek and McIntyre Creek discharge and compared with the analyses of the sample collected near the creek mouth there is no real change indicating no groundwater contribution in the canyon below the gauging station.

16.1.3 Conclusion

A regional pattern shows up in this watershed and similarly snow accumulation and snowmelt above elevations of 4,000 feet are the major sources of runoff and annual groundwater recharge and discharge. Although the groundwater component is significant and provides for a base flow of at least 3.0 cfs daily during the late summer months it is recommended that the above assessment is valid for present planning. Climatological stations should be established in the drainage basins to give precipitation and snow accumulation data and if funds are available it is recommended that an observation well is installed near a snow course and fluctuations of the water table observed in that well can be correlated with the snow course data to provide accurate forecasting.

TABLE 16.1

ANALYSES OF WATER SAMPLES

(in parts per million)

Station Constituent	Fish Lake	Venner Creek	Fish Creek	Mile 22	Vaseux Creek at wier	Vaseux Creek at gauge station	Vaseux Creek at mouth	Vaseux Creek
pH	6.5	8.3	7.9	7.4	7.5	7.8	7.9	7.3
chloride	nil	0.5	0.3	0.3	0.3	0.5	0.5	0.5
Alkalinity $CaCO_3$	nil	nil	nil	nil	nil	nil	nil	nil
alkalinity total	10.5	69.5	99.0	38.0	38.0	78.5	85.5	33.5
hardness	15.6	62.1	95.6	36.6	37.6	76.3	84.6	34.6
conductance	28	142	200	81	82	168	185	78
calcium	3.4	18.4	22.2	10.8	9.2	20.1	22.0	9.0
magnesium	1.7	3.9	9.7	2.3	3.6	6.4	7.2	2.9
sulphate	1.0	3.7	5.5	7.6	3.5	7.5	9.5	5.3
sodium	1.4	3.6	3.4	2.2	2.4	3.6	3.6	2.0
potassium	0.5	1.2	1.4	0.9	0.8	1.2	1.6	1.0
fluoride	0.23	0.18	0.32	0.24	0.31	0.38	0.35	0.1

Analyst: Division of Laboratories, British Columbia Health Services.

16.2 HYDR0GEOLOGY OF VERNON CREEK SUB-BASIN

Vernon Creek drainage basin (Figure 16.2) occupies an area of about 52 Square miles of which more than 35 square miles are above an elevation of 4,000 feet. Long Mountain, the highest point in the basin reaches an elevation of more than 5,400 feet. Lake basins cover more than 1.66 square miles of the upland area and provide basin storage for snowmelt runoff. Discharge from the lakes system flows through Vernon Creek to empty into Ellison Lake some 8 miles distant at an elevation of approximately 1,400 feet. One tributary, dark Creek, drains an area below the 4,250 ft. contour and discharges into Vernon Creek at an elevation of about 1,500 feet.

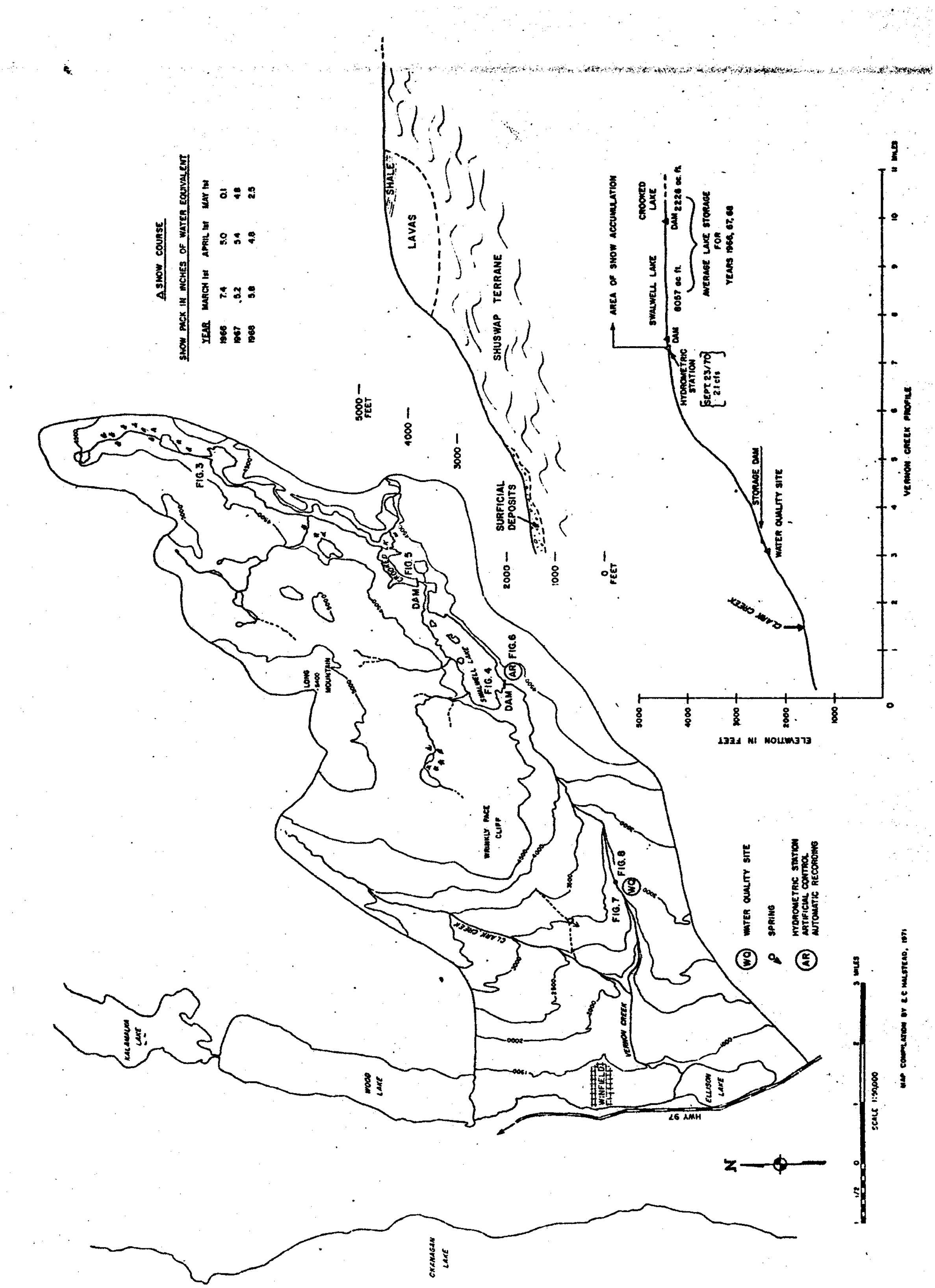
16.2.1 Geology

The basin is underlain by metamorphic rocks of the Shuswap terrane that commonly occupies much of the eastern upland area adjacent to the Okanagan drainage system. Overlying these metamorphic rocks and occupying an area west of Swalwell Lake including Wrinkly Face Cliff are some shales and lavas that at most are not more than 500 feet thick. The lavas flowed out over an erosional surface on the Shuswap terrane during the Tertiary period and it is inferred that the lake depressions could be remnants of this erosional surface. Thereafter glacial ice covered the area and with the disappearance of the ice the upland area was covered with a thin mantle of silt and silty till whereas below 3,000 feet the bedrock is covered in general with morainal deposits washed and channelled by meltwater overlain at lower elevations by poorly sorted gravel, sand, silt and clay that form the delta of the present Vernon Creek.

The mantle of silty sandy clay and till supports a cover of immature timber above an elevation of 3,500 feet (Photo 16.3).

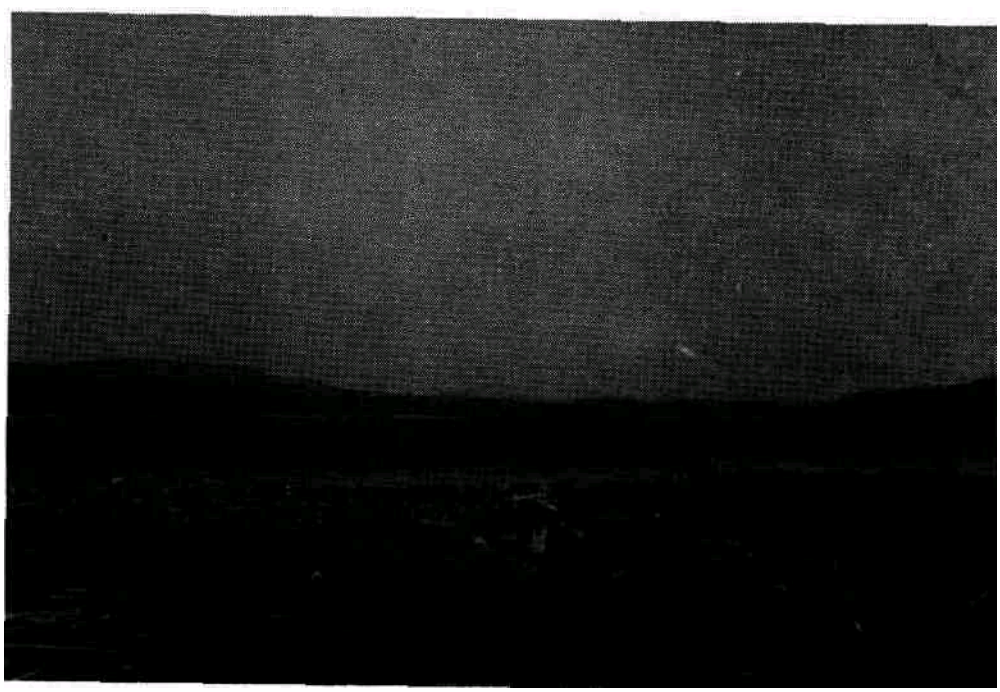
16.2.2 Hydrology

Climatological stations have not been established in the drainage basin but beyond its eastern limit and at an elevation of 4,300 feet a snow course has been in operation for more than 30 years. The water equivalent on April 1st at this point is commonly in the order of 5 inches. The volume of meltwater from this snowpack is the recharge for basin storage in the lakes, soil moisture and groundwater storage in the underlying soils and rocks and provides for runoff that typically reaches a peak in May. Records for the years 1966, 1967 and 1968 indicate the 3 year average storage from the snowmelt in the Vernon watershed amounted to 8,057 acre feet for Swalwell Lake (Photo 16.4) and 2,226 acre feet for Crooked Lake. The discharge of this lake storage is controlled



VERNON CREEK DRAINAGE BASIN Figure 16.2

Photo 16.3 Vernon Creek Drainage Basin, unconsolidated
surficial deposits with stand of immature timber



P
hoto 16.4 Swalwell Lake, September 1970

by dams at the west end of both lakes (Photos 16.5 and 16.6) and therefore flow through Vernon Creek is regulated. Groundwater recharge and discharge within the basin supports the vegetative cover but its contribution to base flow of Vernon Creek is not considered sufficient to warrant further investigation. Discharge of groundwater was noted in September at a spring line at an elevation of about 2,700 feet at the contact of permeable silts overlying a till section at least 200 feet thick. Collective discharge of these springs was less than 3 gallons a minute and supported a growth of cedars and aspens. Below the spring line groundwater continued to seep through a fracture in the till and at the cutbank of Vernon Creek amounted to an immeasurable volume (Photo 16.7) dark Creek was dry below about 2,750 feet elevation but discharge above that point was sufficient to supply water to a logging operator and the volume was In the order of less than 0.2 cfs.

A sample of water was collected at a point at an elevation about 2,250 feet and below present construction for a storage dam (Photo 16.8). The quality of the water, Table 16.1, reflects that of surface water in storage in the lakes and hence confirms the inference that groundwater discharge is minimal.

16.2.3 Conclusion

The regional pattern also shows up in this watershed where at elevations of more than 4,000 feet snow accumulates and its meltwaters contribute to the storage of surface water and runoff providing the typical annual discharge pattern. Following the peak discharge, flow through Vernon Creek is controlled. Further groundwater investigations are not recommended for the Vernon Creek drainage basin.

Photo 16.5 Earth dam, west end of Crooked Lake with discharge outlet

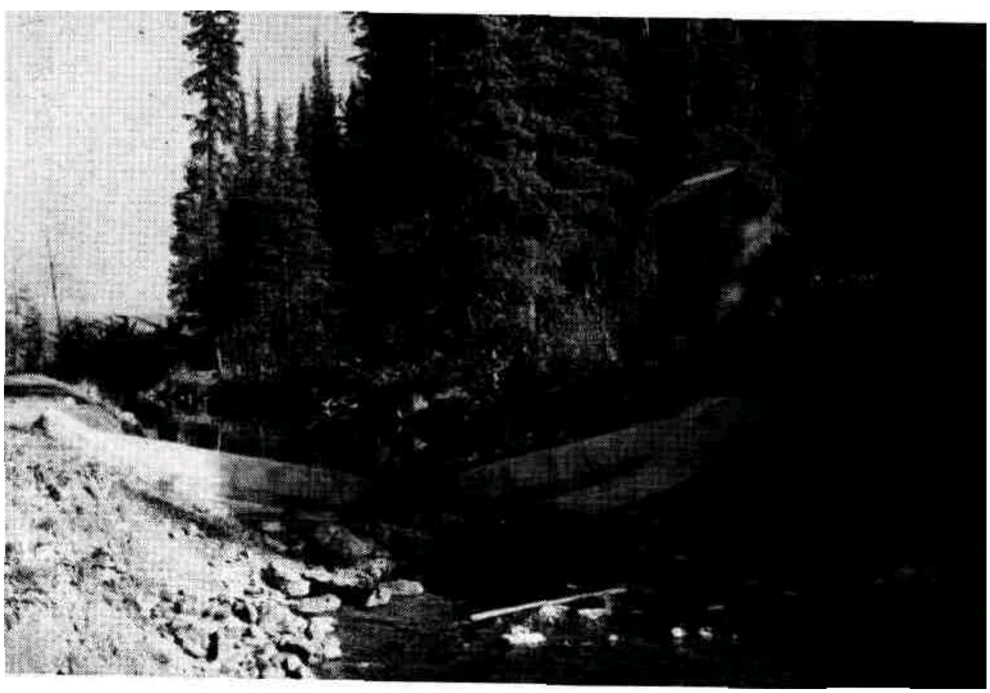


Photo 16.6 Hydrometric Station, 600 ft. downstream from outlet of Swalwell Lake

Photo 16.7 Groundwater discharge through fractured till, road cut to Photo 16.8

Photo 16.8 Storage dam under construction on Vernon Creek, September 1970

16.3 HYDROGEOLOGY OF PENTICTON CREEK SUB-BASIN.

16.3.1 General

Penticton Creek drainage basin is located on the east side of the main Okanagan Valley near the City of Penticton (Figure 16.3). The drainage basin covers some 67 square miles and extends from latitude 49° 30' to 49°40' and longitude 119°35' to 119°20'. The elevation ranges from approximately 1,100' at the City of Penticton to some 7,000 at Greyback Mountain.

16.3.2 Morphology

a) Geology.

The bedrock is comprised of gneisses and schists of the Shuswap Complex and is associated the late Mesozoic Okanagan intrusives. The bedrock is exposed in numerous places and is covered by a thin veneer of Glacial deposits, mainly till and ice-contact material.

It appears that Penticton Creek is structurally controlled, as can be seen on the photo mosaic, there is a NNE-SSW lineation, which is approximately parallel to Penticton Creek. There are seven tributary creeks to the main creek, all are at right angles to the NNE-SSW trend, the tributaries to the tributary creek are again at right angles, i.e. parallel to the NNE-SSW trend. Of the seven tributary creeks, five are on the east side of the basin.

b) Elevation

The following table shows the areas between different contours:

TABLE 16.2

AREA - ELEVATION DATA - PENTICTON CREEK

Contour Interval	Area in Square Miles	% of Total area			
> 2500	4.15	6.18			
2500 - 3000	2.05	3.05			
3000 - 3500	2.36	3.51			
3500 - 4000	3.10	4.62			
4000 - 4500	5.50	8.20			over 4000 ft 82.62%
4500 - 5000	8.90	13.25		over 4500 ft 74.42%	
5000 - 5500	16.52	24.60	over 5000 ft 61.17%		
5500 - 6000	16.29	24.25			
6000 - 6500	7.67	11.40			
6500	0.65	0.97			
	67.19	100.03			

16.3.3 Hydrology

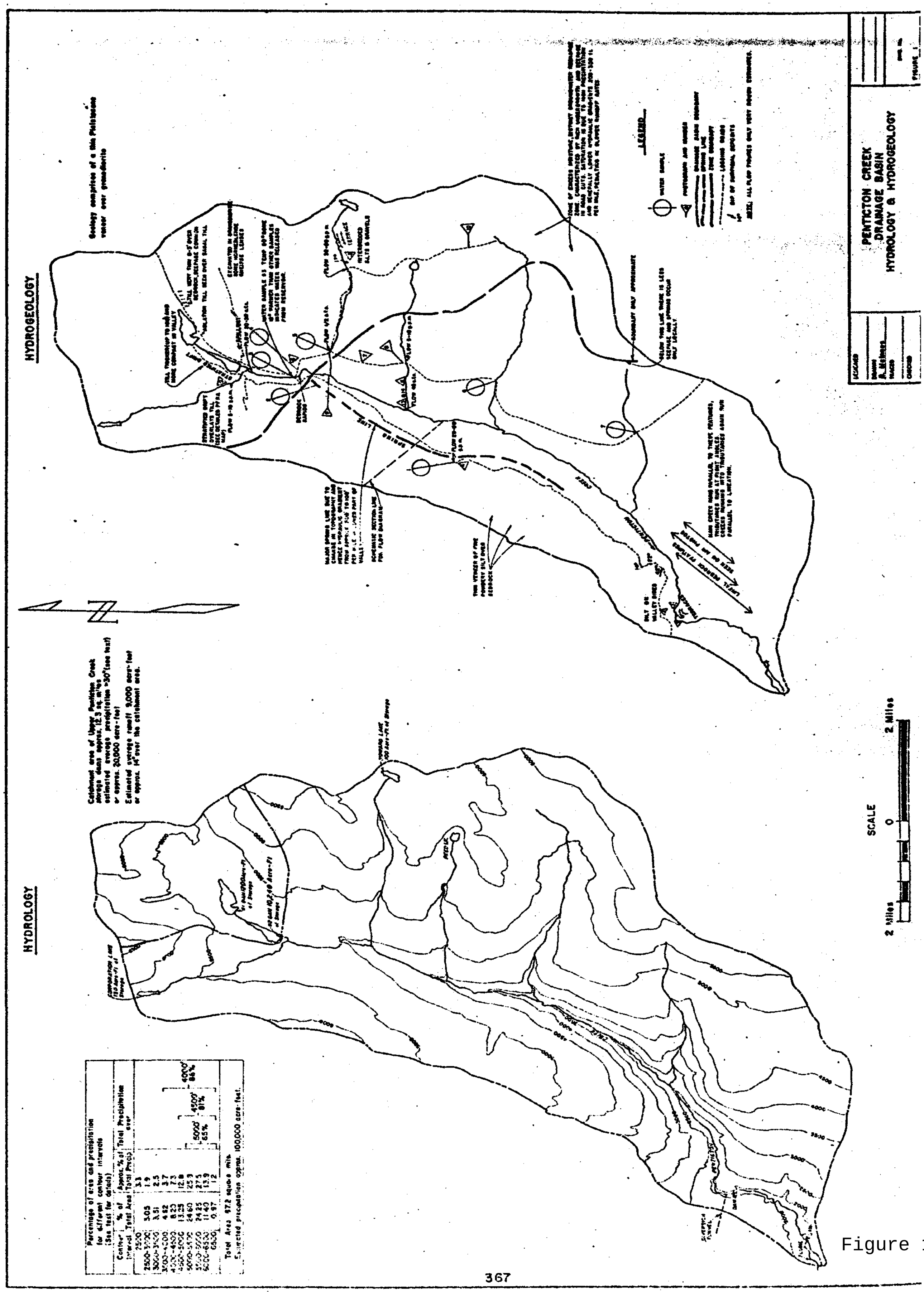


Figure 16-3

a) Precipitation

Records are available from Penticton for the period 1907-1953, later records are probably available but the following averages are based on these figures:

Mean Annual Precipitation 11.31" Minimum 1928 - 1929 5.73" Maximum 1948 - 1949 18.47"

Monthly Averages:

	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT
Precip. in.	0.94	0.94	1.12	1.03	0.80	0.67	0.77	1.10	1.33	0.86	0.86	0.89
% of total	8.31	8.31	9.90	9.12	7.07	5.92	6.81	9.73	11.76	7.60	7.60	7.87

The Hydrology Division of the Water Investigations Branch has developed the following multiple regression equations to calculate precipitation in the Okanagan from elevation, latitude and longitude.

The equations are given below:

$$Y_1 = 0.46X_1 + 4.29X_2 - 206.3$$

$$Y_2 = 0.267X_1 + 2.574X_2 - 124.49$$

$$Y_3 = 0.238X_1 + 2.098X_2 - 101.61$$

Where X_1 = elevation in hundreds of feet

X_2 = Latitude e.g. 49°20'

and Y_1 = Mean annual precipitation in inches

Y_2 = Oct. March mean precipitation in inches

Y_3 = Nov. March mean precipitation in inches

Penticton Creek extends from latitude 49°30' to 49°40' which gives an approximate increase of half an inch of mean annual precipitation in the north of the basin.

b) Limitation of the Equations

The equations are based on data from below 4,000 and so are not verified above this.

The confidence limits of the values ace not calculated here, as the main purpose of using them is to show the areal distribution of precipitation over the basin. More detailed studies of the hydrology and meteorology are being carried out by other task forces.

c) Mean Annual Precipitation

TABLE 16.3

MEAN ANNUAL PRECIPITATION

over over over

Contour Interval	Mean Elevation	Area in square miles	Mean Annual in inches	Precipitation acre feet
2500	2100	4.15	14.86	3,288
2500 - 3000	2750	2.05	17.85	1,951
3000 - 3500	3250	2.36	20.15	2,535
3500 - 4000	3750	3.10	22.45	3,711
4000 - 4500	4250	5.50	24.75	7,259
4500 - 5000	4750	8.90	27.05	12,838
5000 - 5500	5250	16.52	29.35	25,856
5500 - 6000	5750	16.29	31.65	27,494
6000 - 6500	6250	7.67	33.95	13,886
6500		0.65	36.02	1,248
		67.19		100,066

5000′ 4500′ 4000′

68,484 81,322 88,581 =
68% = 81% = 88%

Table H.3 shows that less than 5% of the precipitation falls below 3000′ mainly due to the small area below 3000′ (10% of total area). Yet 88% of the precipitation is derived from 4000′ and higher, 81% from 4500′ and higher and 68% from 5000′ and higher, Figure 16.3.

TABLE 16.4

Y_2 October - March Precipitation

(Penticton Creek)

Mean elevation between controus	October - March inches	Precipitation acre-feet	Cumulative Total
2100	8.02	1,774	55,901
2750	9.75	1,066	54,127
3250	11.09	1,395	53,061
3750	12.42	2,053	51,666
4250	13.76	4,035	49,613
4750	15.09	7,163	45,578
5250	16.43	14,471	38,415
5750	17.76	15,430	23,944
6250	19.10	7,811	8,514
6700	20.30	703	
		55,901	

As can be seen in Table 16.4, just over half of the mean annual precipitation falls from October to March. It should be borne in mind that a large part of the October - March precipitation occurs as snow and remains on the ground until the spring thaw.

d) <u>Surface Runoff</u>

A Praire Farm Rehabilitation Administration Report of 1963 indicates that the 25 year average runoff (prior to 1963) is some 43,000 ft. or approximately "equivalent to 12" over the whole basin (Figure 16.4).

If the total precipitation over the basin is in the region of 100,000 acre-feet, as calculated from the regression equation, then approximately half of the precipitation is lost in evaporation, it will be shown that groundwater outflow from the basin is negligible. Of course, both the estimates of runoff and precipitation are subject to considerable error, but will be refined as the study continues.

One of the problems on Penticton Creek is the number of man-made storage schemes.

The Upper Penticton Creek storage reservoir consists of two dams, #1 dam capable of storing 1,200 acre-feet and #2 dam storing 10,240 acre-feet. The catchment area is approximately 12.3 square miles and the estimated average runoff is 8,900 acre-feet or 13.6". The minimum estimated runoff is 2,000 acre-feet or 3.1".

The average runoff of 13.6" appears low if the estimate of precipitation of 30" or so, for 5000 and higher, is correct. There is a much thicker Pleistocene cover over this area and it could be that the groundwater runoff from this area is much higher than the rest of the basin.

In addition to the Upper Penticton Creek reservoir, there is 100 acre-feet of storage on Howard Lake and 150 acre-test on Corporation Creek.

It is thus quite difficult to estimate the natural flow. Stream gauges are being installed on the Upper reservoir, to determine reservoir storage, below the upper dams to determine flow released from then and just above the dam at Campbell Mountain, to measure the flow going into the lower storage area and diversion tunnel.

The spring snowmelt generally begins in April and proceeds upwards at an approximate rate of 500 per week until the snow melts on the 7000 peaks in late June.

The peak runoff generally occurs in late May and is in the order of 200-300 cfs. According to references, the natural flow in July, August and September is 20 acre-feet per day or 10 cfs with flows as low as 5 acre-feet per day (2.5 cfs).

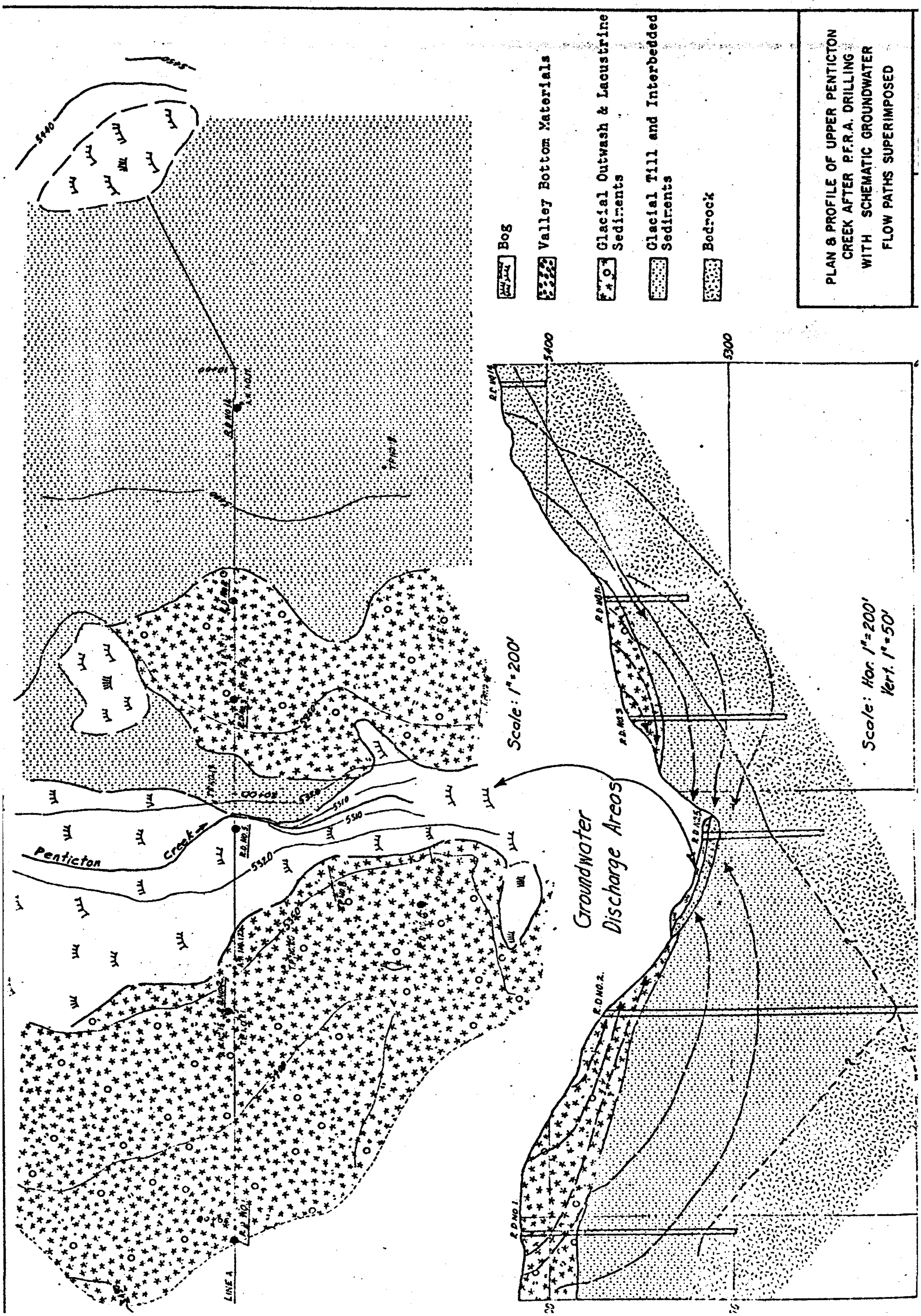

Bog
Valley Bottom Materials
Glacial Outwash & Lacustrine Sediments
Glacial Till and Interbedded Sediments
Bedrock
PLAN & PROFILE OF UPPER PENTICTON CREEK AFTER P.F.R.A. DRILLING WITH SCHEMATIC GROUNDWATER FLOW PATHS SUPERIMPOSED
Penticton Creek
Scale: 1"=200'
Groundwater Discharge Areas
Scale: Hor. 1"=200' Vert. 1"=50'

FIGURE 16-4

If we take the low flows as being mainly groundwater discharge, then say ground-water discharge is 7 cfs or approximately 5000 acre-feet per year and assuming the value of 43,000 acre-feet is correct for average natural discharge, then the groundwater component of the discharge (baseflow) is in the order of 11.5%.

e) Groundwater Flow

As has already been mentioned, the groundwater component of the hydrograph is possibly in the 5% - 15% range of total flow. In addition to this, there will be a certain amount of groundwater flow out of the basin. There are thus two factors to consider:

1. The effect of groundwater flow within the basin, this will generally affect the shape of the discharge hydrograph and be a major influence on low flows.
2. The amount of water actually leaving the basin as groundwater flow.

f) Amount of Groundwater Leaving the Basin

As the Pleistocene deposits are only a thin veneer over the bedrock, we will consider the hydraulic properties of the bedrock.

The bedrock is generally highly metamorphosed (gneiss, granodiorite) and so the hydraulic conductivity will be dependent on the structure i.e. joints, fissures and sheer zones. There appears to be a pronounced joint system running approximately parallel to the main creek (NNE-SSW) and at right angles to this; both are nearly vertical. In addition, there appears to be a smaller system associated with a foliation structure dipping generally to the SW.

These joints have been opened to several centimeters by surface weathering and undoubtedly close up with depth. Test drilling for the diversion tunnel at Campbell Mountain indicated fine fissures up to 140' below the surface with inflows of up to 1 gpm in the test holes. No detail was given on the diameter of the hole or depths at which water came up.

It thus appears that the hydraulic conductivity, k, could probably be expressed as a function of depth and would probably be insignificant below depths of say 500 - 1000'. So there would be very little groundwater outflow from the basin, other than near the mouth of the creek and possibly minor amounts near the topographic divides.

The Prairie Farm Rehabilitation Administration drilled a test hole in the valley bottom near the site of the diversion tunnel and dam. This test hole indicated there was some 70 feet of overburden above bedrock, although it may be that the hole was terminated in a large granitic boulder.

Field permeability tests gave values in the range of 0.06 to 0.3 ft/ min., which is approximately 5.5×10^2 us gpd/ft.^{2} to 2.8×10^3 us gpd/ft.^{2}*.

The authors of the report assume a hydraulic head differential of 25' at the dam, a flow path of 250 feet and a cross-sectional area of 13,000 square feet.

From this they derive an underflow of from 2-10 cfs.

Using D'Arch's Law

$Q = KIA$ Where Q = flow in us gpd

K = hydraulic conductivity us gpd/ft.^{2}

I = hydraulic gradient

A = Cross sectional area

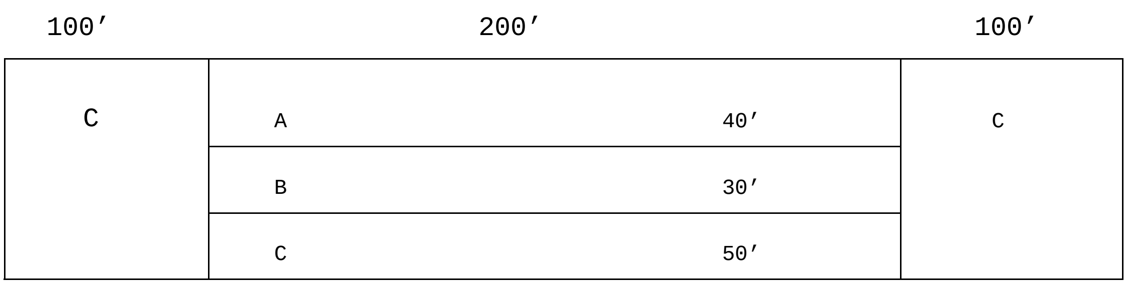
$Q = 5.5 \times 10^2 \times 25/250 \times 13{,}000 = 7.1 \times 10^5$ us gpd/ft.^{2}

$Q = 2.8 \times 10^3 \times 25/250 \times 13{,}000 = 3.6 \times 10^6$ us gpd/ft.^{2}

Dividing by 6.46×10^5 to obtain flow in cfs, we have:

Q = 1.1 to 5.5 cfs.

To make a rough estimate of the natural flow through the channel above the dam, where the new weir will be sited, consider the following simplified cross section:



Where: A = coarse gravels and boulders

B = fine sands

C = fractured bedrock

If we assign the following hydraulic conductivities to each unit:

	Cross sectional area A
$K_A = 10^4$ us gpd/ft^2	A_A = 8,000 ft^2
$K_B = 10^2$ us gpd/ft^2	A_B = 6,000 ft^2
$K_C = 10^0$ us gpd/ft^2	A_C = 34,000 ft^2

* to convert to us gpd/ft.^{2} multiply ft/min. by 1.075×10^4

And assume a hydraulic gradient of approximately 150 ft/mile (the same as the creek bed).

We have: $Q = KIA$

$Q_A = 10^4 \times 150/5000 \times 8000$ us gpd approx. 2.4×10^6 us gpd

$Q_B = 10^2 \times 150/5000 \times 6000$ us gpd approx. 1.8×10^4 us gpd

$Q_C = 10^0 \times 150/5000 \times 34,000$ us gpd approx. 1.0×10^2 us gpd

Total approx. 2.4181×10^6 or approximately 3-4 cfs.

g) Groundwater Flow Within the Basin

As has already been mentioned, the geology of the basin comprises of a thin veneer of Pleistocene deposits over gneissic bedrock. The Pleistocene deposits vary from silts, sands and till to gravels with extremely rapid lateral variations.

A theoretical groundwater flow pattern is described below this is based on work by Toth (1962, 1963) and Freeze (1966, 67a, 67b). Toth suggests a system of three major flow components: (1) local, (2) intermediate, (3) regional. Due to the decreasing permeability of the bedrock with depth, it is suggested here that the regional flow between drainage basins is negligible or absent. It is further proposed that there be two flow zones for Toths's local flow system, these are designated K_A and K_B, the term K_C is used for the intermediate flow path.

h) Local flow Zone K_A

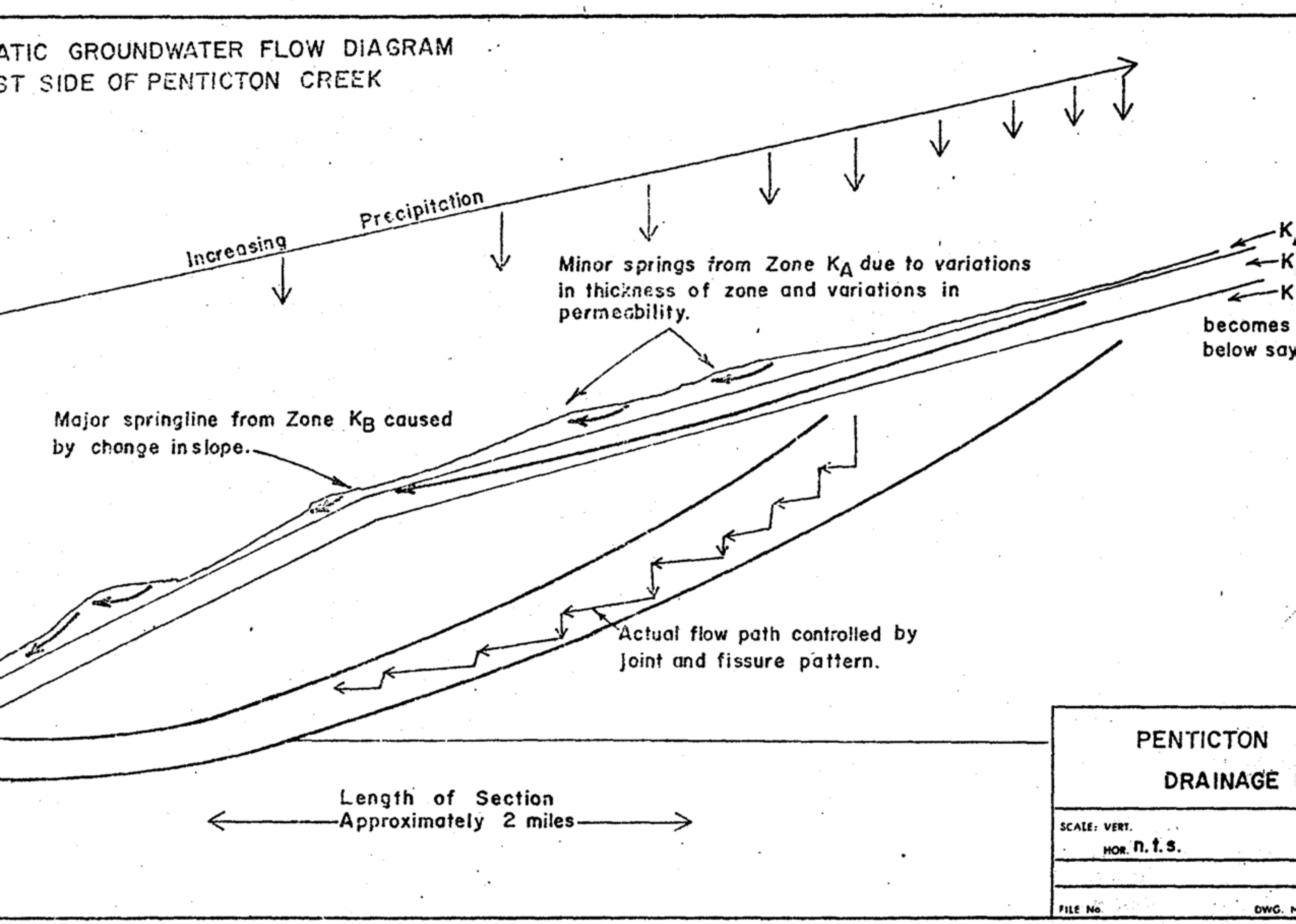
It is proposed that the upper part Pleistocene cover be designated a local flow zone; in places this zone would extend down to bedrock, in others, the lower part of the Pleistocene may be better grouped with zone K_B. The zone K_A is characterized by numberous small flow systems (See Figure 16.5.

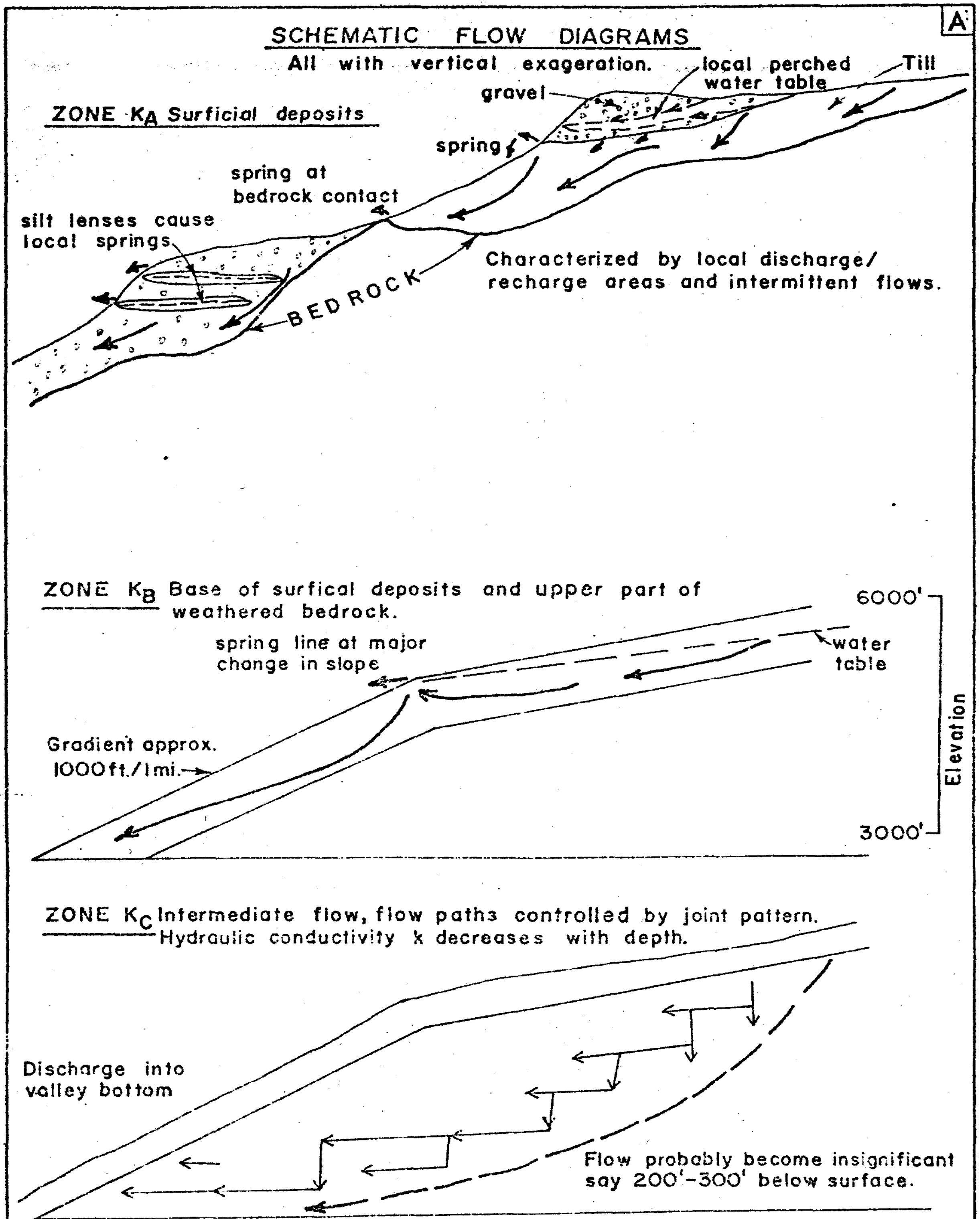
Local springs are caused by variations in topography and lithology, some characteristic situations causing springs are shown in Figure 16.5.

During August 1970, field examination showed that most of the springs had ceased flowing or were only discharging at 5-10 us gpm, this was due to the low precipitation and high evapotranspiration. This emphasizes the seasonal variations within this zone, much higher flows would be expected after the snowmelt period and also after heavy rains.

i) Zone K_B

This zone would be an extension of zone K_A, it is shown in Figure 16.6. This zone would comprise of the lower part of the Pleistocene, the fractured tills and leached zones. It also includes the upper few feet of the bedrock where the joints are opened by weathering, this zone would extend 5-10 or 20 feet


ATIC GROUNDWATER FLOW DIAGRAM
ST SIDE OF PENTICTON CREEK
Increasing
Precipitation
Minor springs from Zone K_A due to variations in thickness of zone and variations in permeability.
Major springline from Zone K_B caused by change in slope.
Actual flow path controlled by joint and fissure pattern.
becomes
below say
Length of Section
Approximately 2 miles
PENTICTON
DRAINAGE
SCALE: VERT.
HOR. n. t. s.
FILE No.
DWG.



PENTICTON CREEK

DRAINAGE BASIN

n.t.s.

FIGURE 16-6

below the bedrock surface. The hydraulic conductivity of this zone would be generally higher than that of the overlying zone and would probably be extremely variable, from say, 1 to 100 us gpm per ft. This zone will in general, be more uniform than zone K_A and will show smaller water level fluctuations.

To measure the amount of water flowing through this zone, we could use the following elementary formulae.

$Q = PIA$ Where P = Permeability
I = Hydraulic grad
$Q = VA$ A = Cross section area
V = Velocity

The hydraulic gradient 'I' could be assumed to be nearly the same as the topographic gradient, pressure tests would give permeability and also a possible depth at which this zone could be terminated. Alternatively velocity, V, could be obtained from injecting tracers.

One feature of this zone is the major spring line at approximately 5000 ft. where there is a distinct break in slope. Above this elevation the topographic gradient is approximately 500 ft/mile while below it is in the order of 1000 ft/ mile. This shows that the hydraulic conductivity, K, is such that it will support a hydraulic gradient of 500 ft/mile but not 1000 ft/mile, alternatively there could be a change in hydraulic conductivity at the change of slope, for example, till could be plastered against the lower part of the slope. Most of the groundwater movement probably occurs within this zone.

j) Intermediate flow Zone K_C

This zone would be entirely within bedrock and would begin at some arbitrary depth at which there is a specific decrease in hydraulic conductivity. As has been stated earlier, hydraulic conductivity, K, decreases with depth, a Prairie Farm Rehabilitation Administration test hole at the site of the diversion tunnel found a permeability of 1/2 us gpd/ft^2 at a depth of 138' below surface. It is thus probable that flow becomes insignificant beyond depths of say 2000' and for mathematical simulation an impermeable boundary could be assigned to varying depths, say 200-500 ft. It is thus evident that there would be no significant flows between basis and the groundwater from this zone would discharge into the valley bottom.

It is proposed that no regional flow component be created, for the above reasons.

Mathematical models developed by Freeze (1966), could be utilized to aid in the interpretation of the groundwater flow system. This would involve assigning relative values of K to a multilayered aquifer system.

Studies by Lawson (1968), on the Trapping Creek Basin 30 miles east of Penticton Creek, using six permeability zones, three of which are similar to those proposed in this report and a further three zones of higher permeability in the valley bottom.

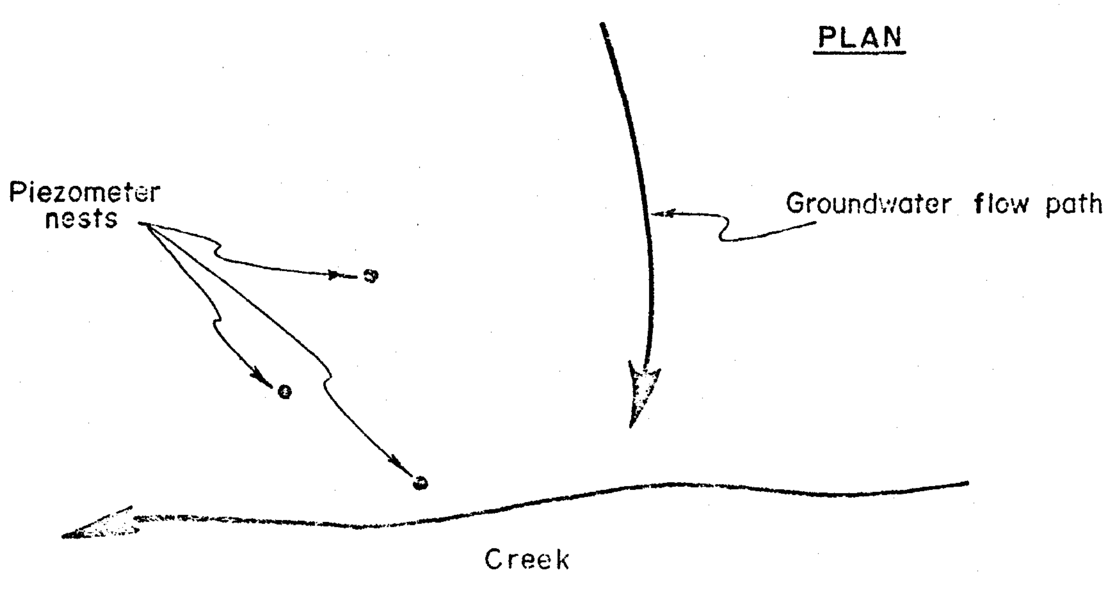
Lawson postulates that piezometers cannot be reliable beyond depths of 175 feet, due to the decreasing and more random frequency of fissures with depth. He further postulates an impermeable boundary at a dept of 1,000 feet and suggests most of the groundwater movement (95%) occurs in the local flow system (zones K_A and part of K_B in this report). Lawson reports permeabilities higher than the Praire Farm Rehabilitation Administration figures in the report, this may be due to differences in geology, there being more permeable tuffs present in Trapping Creek. Lawson gives values of permeability as follows:

> Local flow zones (0-150') 10-17 igpd/ft. thickness (zone K_A and part K_B) Intermediate flow zone (est. at 150') 6.8×10^{-3} igpd/ft. thickness Regional flow zone (est. at 600') 8.0×10^{-15} igpd/ft. thickness

To check any theory in the field would be expensive, involving the installation of piezometers. This is discussed under instrumentation.

k) <u>Instrumentation</u>

In order to measure groundwater fluctuation in the field, it would be necessary to install piezometers, a minimum of three nests in any profile would be necessary to define the water-table plane (see diagram below).



At each nest, at least one piezometer would have to be installed within each of the three proposed flow zones. Due to the steep hydraul1c gradients (I) and the relatively high velocities associated with fissure flow, in conjunction with a low storage coefficient (S) watertable fluctuations will be both rapid and relatively large. Consequently, the water level should be monitored by recorders rather than manually.

It would cost $500 to $2,000 to drill each hole, it may be that nests of peizometers could be completed at different depths within each hole or different holes may have to be drilled for each depth, depending upon conditions and hole diameter.

Recorders would costs approximately $500 for a single channel, with multi channel recorders costing more (for different piezometers) so costs would vary from say $3000 to $6000 per piexometer nest.

There would also be the cost of access roads to each site at a cost of $2000 -$3000 per mile.

As stated, a minimum of three piezometer nests would be required to monitor one section. This, in itself, may not be representative of conditions a short distance away.

In summary, it is concluded that it would not be justifiable to install a piezometer network due to the high capital cost and relative small returns.

1) "V" Notch Heirs

One alternative is to install small weirs at numberous strategic points and analyze the hydrograph for the base flow component. Data from these weirs could also be used to simulate surface water runoff using flood routing techniques.

The weirs are described by Hall and Langham (1970), and are constructed

of 3/4" or 1" plywood, reinforced with metal angle iron and have a metal lip on the "V" notch to give a sharp chrest. The rating curve of the weir will depend upon the angle of the notch, the capacity can be from approximately 7-12 cfs for a two-foot head on a 60° or 90° "V" notch; other angles could be constructed for less than $250, an F-type recorder would cost approximately $450; with installation the weirs would cost approximately $1000.

These weirs could be installed on the tributary creeks and at different elevations on one of the six basins under study.

In the International Hydrological Decade (I.H.D.) study basin at Carr's Landing, the Hydrology division has reported a good correlation between water-table fluctuations and snowmelt runoff.

One possible explanation is as follows: Apart from the meteorological effects upon runoff from snowmelt, the actual amount of water melting will go partly towards surface water runoff phenomena and partly as groundwater phenomena. This in turn will affect the peak flow and its duration, higher peaks and shorter duration high flows will be experienced when the surface water runoff is more important.

The percentage surface runoff to groundwater will depend upon the permeability of the soil, amoung other factors. The permeability of the soil will in turn be affected by the amount and type of frost in the soil at the time of snowmelt. The frost seal will depend partly upon soil moisture levels prior to freezing and also upon precipitation and evaporation prior to snowfall and the type of frost will depend upon freezing conditions prior to snowfall and the insulating effects of the snowfall. There may also be substantial evaporation/condensation within the soil moisture - snowpack system, depending upon vapour pressures.

Thus monitoring the water-table may give a good index to be used in extimating runoff from snowmelt.

If possible, small closed local flow systems should be instrumented with recording piezometers. If properly designed, the piezometers may also measure evapotranspiration in the summer. Thermistors installed at different depths in the soil may also give useful indexes to the frost seal and would give information on infultration rates during the spring, summer and fall.

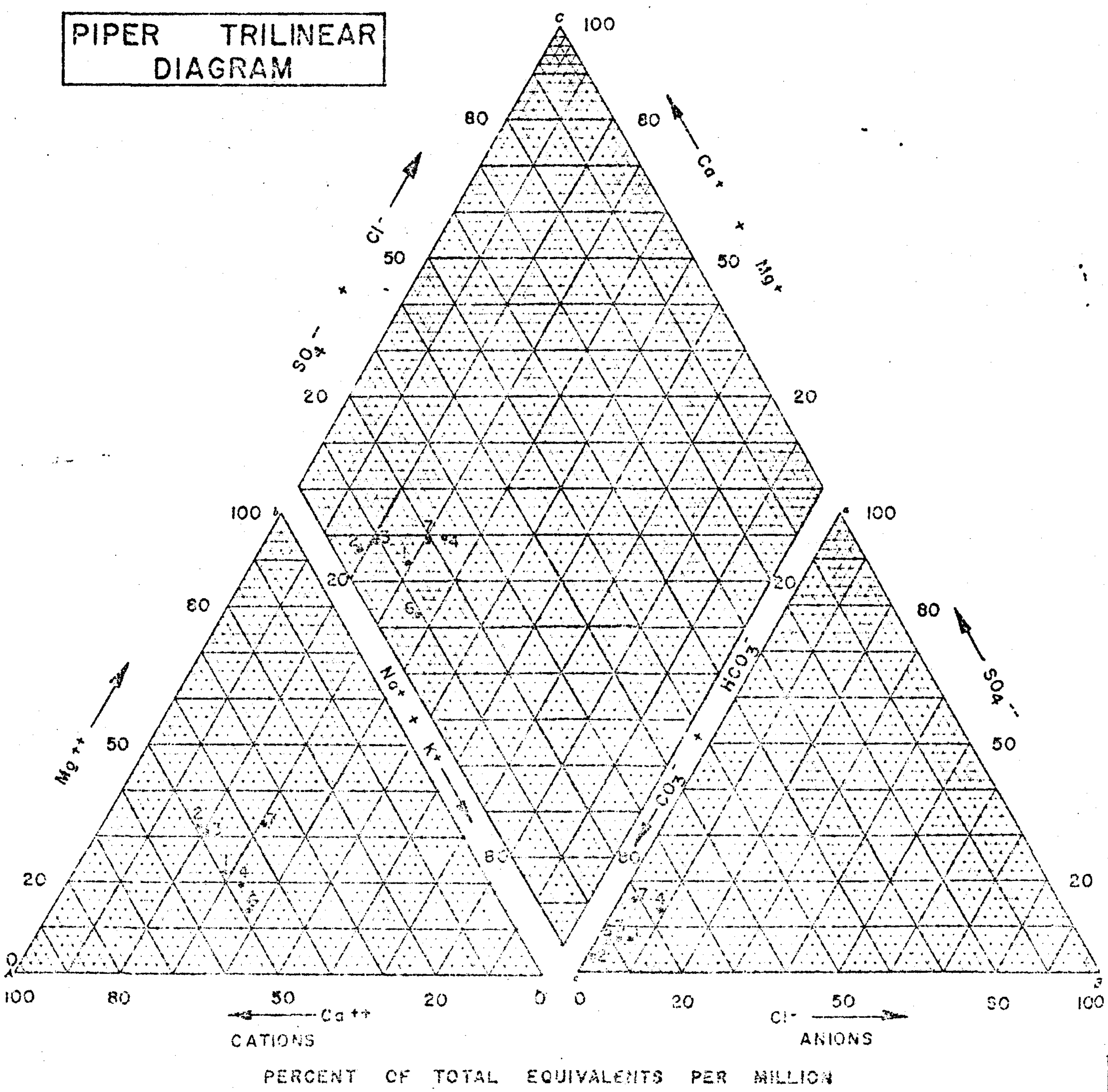
m) <u>Hydrochemistry</u>

Seven samples of water were collected from Penticton Creek and its tributaries, these were analysed by the Public Health Department. The locations where the samples were taken from are shown on Figure 16.7. The analyses are shown in the accompanying table end on the Piper diagram.

As can be seen, the waters are relatively fresh, with less than 100 ppm dissolved solids.

The samples are generally calcium, magnesium, bicarbonate waters and there appears to be no real difference between the samples.

In waters this fresh, the anion/cation epm balance should generally be within 5% there is up to 10% difference in some analyses, which makes the analyses somewhat suspect.



WATER SAMPLES FROM PENTICTON CREEK

Figure 16.7

n) <u>The Water Balance</u>

If we consider the following simple relationship

(1) $P = ET + R\ A_s$ Where P = Precipitation
ET = Evapotranspiration
R = Runoff, surface and subsurface
A_s = Change in storage, surface and subsurface

From figures available at this time:

P	approx.	100,000 acre-feet per year	
R_S	approx.	43,000 acre-feet per year	(surface)
R_g	approx.	1-3,000 acre-feet per year	(groundwater)
A_s	approx.	natural storage prob. small	

Potential ET approx. 20" approx. 61,000 acre-feet.

Thus using equation (1)

100,000 aprox. 61,000 + 43,000 + 1 - 3,000 acre-feet

which nearly balances and considering the nature of the data, the balance is quite good.

It can be seen that the groundwater component is quite small even when taking baseflow as 5-15% of runoff (2,000 - 6,000 acre-feet).

o) <u>Errors within the Water Balance</u>

i) <u>Precipitation</u>

Errors in catch by the rain gauge caused by location of gauge, height above ground, type of gauge, wind speed, etc., will add some small error say +- 5% for rain and possible for snow, up to +- 50%.

There is also the problem of extrapolating the guage catch to the rest of the basin.

Estimating the water equivalent of the snow cover over the basin can also lead to considerable errors.

ii) <u>Evapotranspiration</u>

Losses from the snowpack by evaporation and sublimation can be especially high during the snowmelt period. As the snowmelt period extends over several weeks and rises in altitude with time a relatively sophisticated meteorological network would be necessary to estimate losses. Transpiration from the forest cover during summer will also be subject to considerable errors.

iii) Runoff

Weirs generally have an error margin of +- 5%, the error margin of the Penticton weirs win be determined by other task forces.

iv) Storage

If we assume that each of the Upper storage reservoirs has a surface area of approximately 1/4 square mile, or say, 150 acres, then a change of 1/100th of a foot per day win give more than 1 1/2 acre-feet or very nearly 1 cfs inflow or outflow. Thus it will not be possible to measure accurately small changes in storage, especially if one considers the fluctuations due to seiches and winds piling the waters up downwind.

The possible errors in the water-balance have been pointed out to show that many of these errors are of the same or greater magnitude as the groundwater outflow.

16.3.4 Conclusion

The main significance of groundwater in this drainage basin is its affect upon the discharge hydrograph. As the groundwater zone is relatively shallow and as gradients are high then there is probably not sufficient temporary ground-water storage to reduce peak flows significantly, yet there is sufficient storage to provide 5-20 cfs runoff during low flow.

TABLE 16.5
WATER SAMPLES FROM PENTICTON CREEK

Sample No.	1			2			3			4		
	ppm	epm	%epm	ppm	epm	%epm	ppm	epm	%epm	ppm	epm	%epm
ANIONS Cl^-	0.80	0.023	6.50	0.30	0.009	1.39	0.5	0.014	4.78	0.5	0.014	9.10
SO_4^{--}	1.20	0.025	7.19	1.00	0.021	3.42	1.0	0.021	7.06	1.0	0.021	13.44
$*HCO_3^-$	18.29	0.300	86.31	35.36	0.580	95.19	15.85	0.260	88.15	7.32	0.120	77.46
Sum	20.29	0.347	100.00	36.66	0.608	100.00	17.35	0.295	99.99	8.85	0.155	100.00
CATIONS Ca^{++}	4.2	0.210	49.44	7.0	0.350	48.22	3.2	0.160	48.61	2.0	0.10	47.64
Mg^{++}	1.1	0.090	21.34	2.8	0.230	31.79	1.2	0.099	30.04	0.5	0.041	19.63
Na^+	2.2	0.096	29.22	2.8	0.122	19.99	1.2	0.052	21.34	1.4	0.061	32.73
K^+	1.1	0.028		0.9	0.23		0.7	0.018		0.3	0.008	
Sum	8.60	0.423	100.00	13.50	0.724	100.00	6.30	0.328	99.99	4.20	0.209	100.00
Total ppm	28.89			50.16			23.65			13.05		
1 %Anions epm		45			45.6			47.4			42.6	
%Cations		55			54.4			52.6			57.4	
S.A.R.	0.25			0.22			0.145			0.229		
pH	6.7			7.2			6.6			6.5		
Conductivity as micromhos/cm	42			68			27			17		
Total hardness as $CaCO_3$	15.0			29.0			13.0			6.0		
dissolved solids	28.9			50.4			23.7			13.0		

Sample No.	5			6			7		
	ppm	epm	%epm	ppm	epm	%epm	ppm	epm	%epm
ANIONS Cl^-	0.3	0.009	3.69	0.3	0.009	2.74	0.50	0.014	3.69
SO_4^{--}	1.0	0.021	9.09	1.0	0.021	6.74	2.70	0.056	14.71
HCO_3^-	12.19	0.200	87.22	17.07	0.28	90.52	19.02	0.312	81.60
Sum	13.49	0.229	100.00	18.37	0.309	100.00	22.22	0.382	100.00
CATIONS Ca^{++}	3.0	0.150		3.6	0.180	49.76	3.2	0.160	35.96
Mg^+	1.2	0.050		0.6	0.049	13.67	1.8	0.148	33.33
Na^+				2.8	0.122	36.57	2.9	0.126	30.71
K^+				0.4	0.010		0.4	0.010	
Sum				7.4	0.361	100.00	8.3	0.444	100.00
Total ppm				25.77			30.52		
% Anions epm					41.3			46.2	
% Cations					58.7			53.8	
S.A.R.				0.36			0.32		
pH	6.9			6.9			6.9		
Conductivity as micromhos/cm	20			36			35		
Total Hardness as $CaCO_3$	10.0			14.0			15.6		
dissolved solids				26.37			30.44		

Alkalinity as CO_3 nil in all samples. Flouride generally less than 0.1 ppm. *HCO_3 value obtained by multiplying $CaCO_3$ by 1.219214. 1 anion/cation balance should be within:

+- 5% for total solids 100 ppm

+- 3% for total solids 100-250 ppm.

+- 2% for total solids 250 ppm.

Samples #4 and #6 do not balance within limits. The remaining samples are only just within the limits

16.4 HYDROGEOLOGY OF PEARSON CREEK SUB-BASIN 16.4.1 INTRODUCTION

a) General Statement

Movement within this basin is extremely limited due to lack of logging roads.

There is considerably less data available for this basin than Penticton Basin.

Pearson Creek flows into Mission Creek at an approximate elevation of 3,000 feet, Pearson Creek basin rises to approximately 6,500 feet.

The basin is considerably smaller than Penticton basin, being only approximately 30 square miles in area.

Being further north, precipitation is also slightly higher than Penticton Creek. Estimated precipitation is given below in Table 16.6;

TABLE 16.6

ESTIMATED PRECIPITATION OF PEARSON CREEK SUB-BASIN

Contour Interval	Mean Elevation	Area Square Miles	Precipitation	
			Inches	Acre-feet
3000 - 4000	3700	4.2	23	5,200
4000 - 5000	4500	9.6	27	13,800
5000 - 6000	5500	11.4	32	19,200
6000	6300	4.9	35	9,200
		30.1		47,400

Calculations were made the same way as on Penticton Creek.

Assuming an approximate mean annual precipitation of 50,000 acre-feet:

less than 10% falls below 4000 feet.

more than 60% falls above 5000 feet.

more than 20% falls above 6000 feet.

16.4.2 Geology

The area is much the same as Penticton Creek, a Pleistocene veneer over igneous bedrock. Here the main difference is the bedrock type, being basalts and andesites rather than granodiorite.

There is a distinct plateau area above 5,500 feet which is generally poorly drained, due to the low topographic gradients. This area may be suitable for high level observation wells to use as an index of runoff from snowmen. The wells should be sited in an area not influenced by large surface or ground-water inflows and outflows. The wells should also, if possible be completed in fairly permeable deposits, i.e. the drift or upper few feet of bedrock. Wells completed at depth may be affected by irregular storage within fissure zones. That is, a uniform input of water may not produce a regular rise in the observation well due to zones of large permeability (large fissures) and zones of small fissures at different depths.

It is not possible to estimate the amount of groundwater outflow from the basin at the moment as there is no information on the type and amount of surficial materials in the valley bottom. The quantity is probably in the same order of magnitude as Penticton Creek, possibly slightly higher as there appears to be more surficial material.

The baseflow component can be estimated from the hydrographs obtained from the new weir. There is little or not artificial storage to modify the runoff hydrograph.

Movement within the basin is extremely difficult and it would be extremely expensive to verify any theoretical groundwater movement by installing piezometers.

Locations of chemical analyses are shown in Figure 16.8 and results of the water quality analyses are shown on the Piper diagram (Figure 16.9).

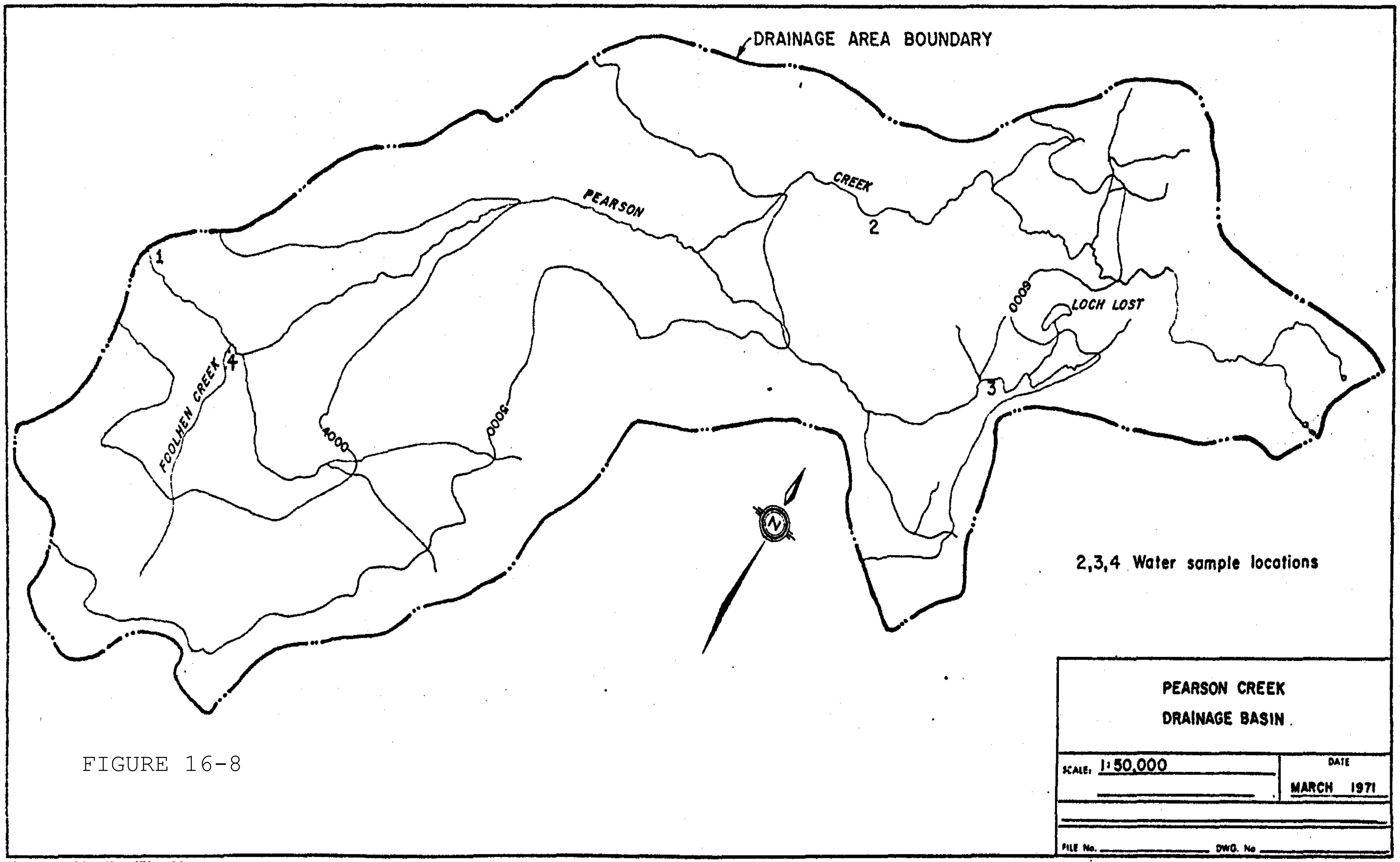
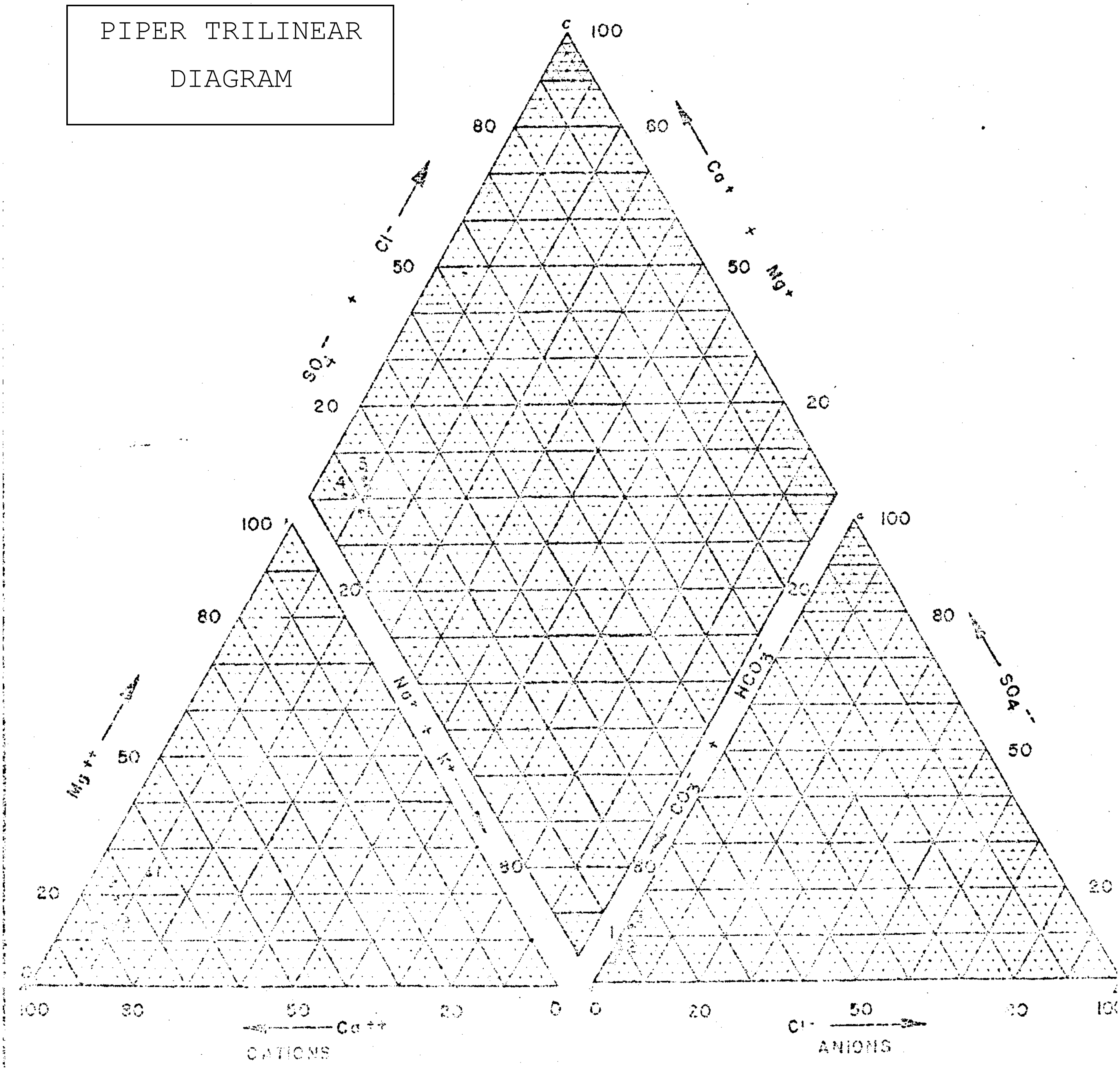

DRAINAGE AREA BOUNDARY
PEARSON
CREEK
LOCH LOST
FOOLHEN CREEK
1
2
3
4
4000
5000
6000
N
2,3,4 Water sample locations
PEARSON CREEK
DRAINAGE BASIN.
SCALE: 1:50,000
DATE
MARCH 1971
FILE No.
DWG. No

FIGURE 16-8

PIPER TRILINEAR DIAGRAM



PERCENT OF TOTAL EQUIVALENT PER MILLION

WATER SAMPLES FROM PEARSON CREEK

FIGURE 16.9

16.5 HYDROGEOLOGY OF LAMBLY CREEK SUB-BASIN

16.5.1 Introduction

a) Methods of Investigation

As sub-basins are virtually unsettled, and study of the groundwater regime must first be directed towards qualitative reconnaissance studies of natural phenomena. This involved field mapping of groundwater features such as spings and seepage sites in relation to topography and geology. Air photos were used to supplement field studies.

16.5.2 Geography

a) Location and Extent of the Area

Lambly Creek drainage basin occurs on the west side of Okanagan Lake, in a direction northwest of the city of Kelowna. The basin lies between parallels of latitude 49°55' and 50°07' north, and meridians of longitude 119°30' arid. 119° 49' west (Figures 16.10 and 16.11). The area of the basin is about 95 square miles. Its elevation ranges from 1,121 feet at Okanagan Lake to 6,134 feet at Whiterocks Mountain.

b) Drainage

Lambly Creek describes an accurate course divisible into 3 portions during its flow from Lambly Lake to Okanagan Lake. Upon leaving its source area, it flows northeast in the upper part, slightly south of east along its central portion and turns southeast in its lowest portion. The major tributary is Terrace Creek which rises in the extreme northwest corner of the sub-basin and generally flows southeast before entering Lambly Creek at about the midpoint of the central portion. The other important tributary creeks are North Lambly Creek which rises in Tadpole Lake flowing mainly from northwest to southeast and occurring about 3 miles west of Terrace Creek, and Bald Range Creek flowing mainly from north to south entering the main creek at a point where it turns southeast. The basin is little affected by man made storage, except at Lambly Creek. Precipitation ranges from about 11 inches at Okanagan Lake to an estimated 36 inches at the highest levels.

c) Vegetation

The area is densely forested preventing access to much of the area. The tree. types are mainly Lodegpole pine with some Douglas fir and Spruce at the higher elevations, above about 3,500 feet, with Douglas fir and Yellow pine predominating below 3,500 feet and in areas of east-facing aspect. Locally poplars

16-10

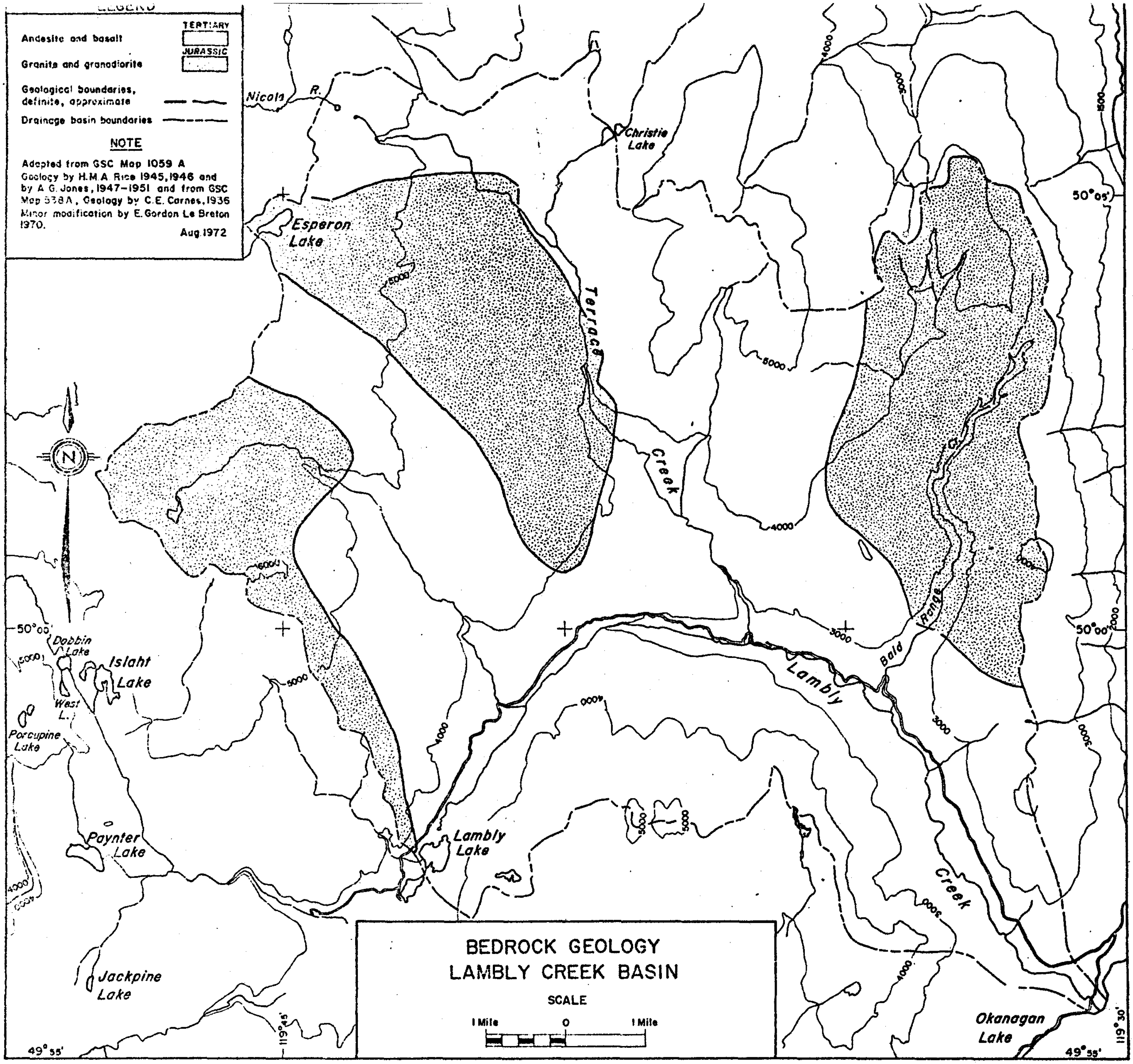
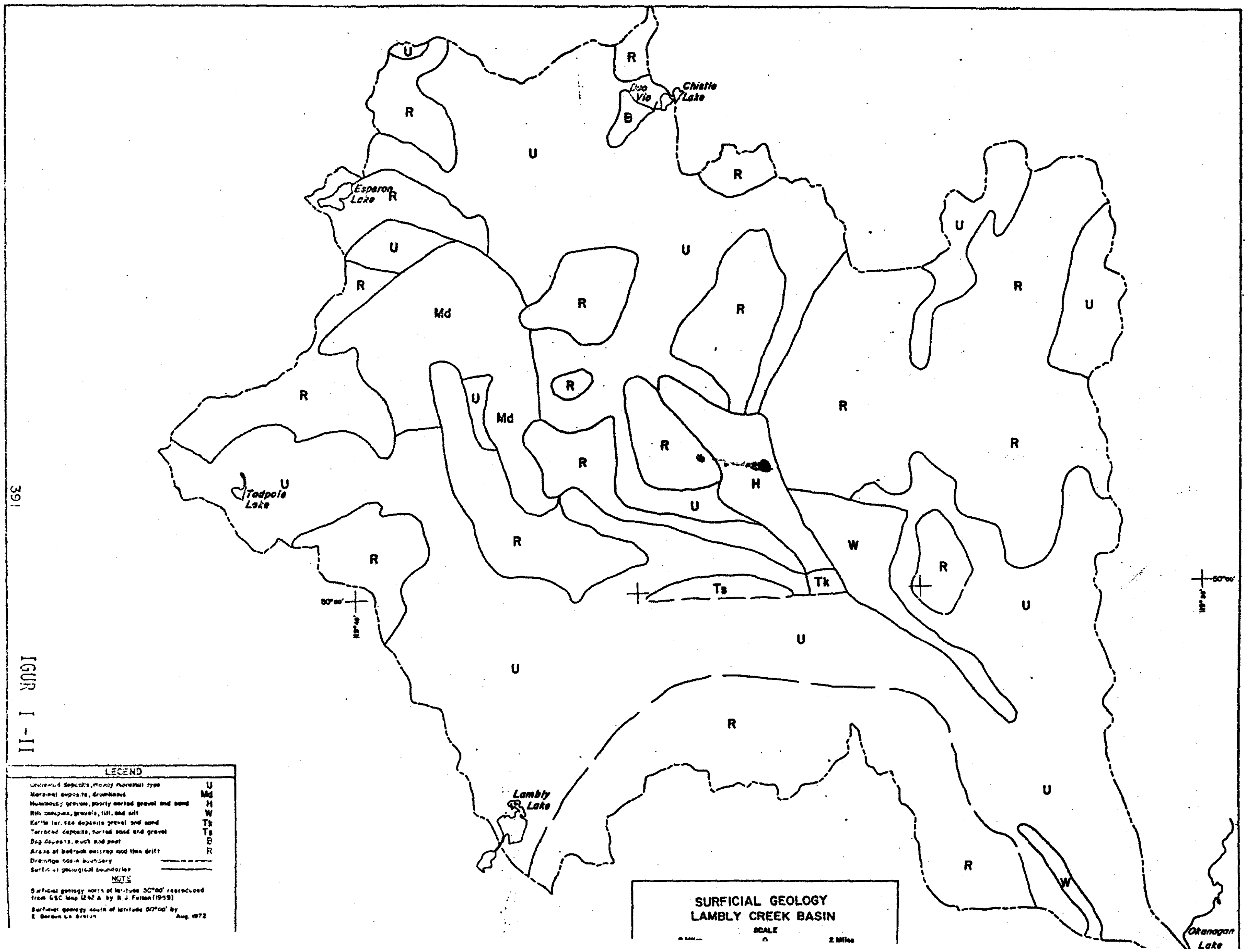

LEGEND
TERTIARY
Andesite and basalt
JURASSIC
Granite and granodiorite
Geological boundaries, definite, approximate
Drainage basin boundaries
NOTE
Adapted from GSC Map 1059 A
Geology by H.M.A Rice 1945,1946 and by A.G. Jones, 1947-1951 and from GSC Map 538A, Geology by C.E. Cornes, 1936
Minor modification by E. Gordon Le Breton 1970.
Aug. 1972
Nicola R.
Christie Lake
Esperon Lake
Terrace Creek
Islaht Lake
Dobbin Lake
West L.
Porcupine Lake
Paynter Lake
Jackpine Lake
Lambly Lake
Lambly Creek
Bald Range
Okanagan Lake
50°05'
50°00'
49°55'
119°45'
119°30'
BEDROCK GEOLOGY
LAMBLY CREEK BASIN
SCALE
1 Mile
0
1 Mile

FIGURE 16-11


SURFICIAL GEOLOGY
LAMBLY CREEK BASIN
SCALE
2 Miles
LEGEND
NOTE
Aug. 1972
Esperon Lake
Chistle Lake
Tadpole Lake
Lambly Lake
Okanagan Lake
U
R
Md
H
W
Tk
Ts
B

occur and are found within the elevation range from about 3,000 to 4,500, feet.

16.5.3 Geology

Bedrock geology is comprised mainly of two rock types, intrusive igneous rocks chiefly granite and granodiorite of Jurassic age, and extrusive igneious rocks, chiefly andesite and basalt of Tertiary age (Figure 16.10). These rocks, which have not been subjected to structural influences produced by earth movements can be expected to have fracture patterns formed during natural cooling processes and by weathering. Rectangular type fracture patterns were observed during field work but no particular predominating trend seemed to be apparent from which qualitative inferences may be drawn concerning fracture permeability influences on groundwater movement.

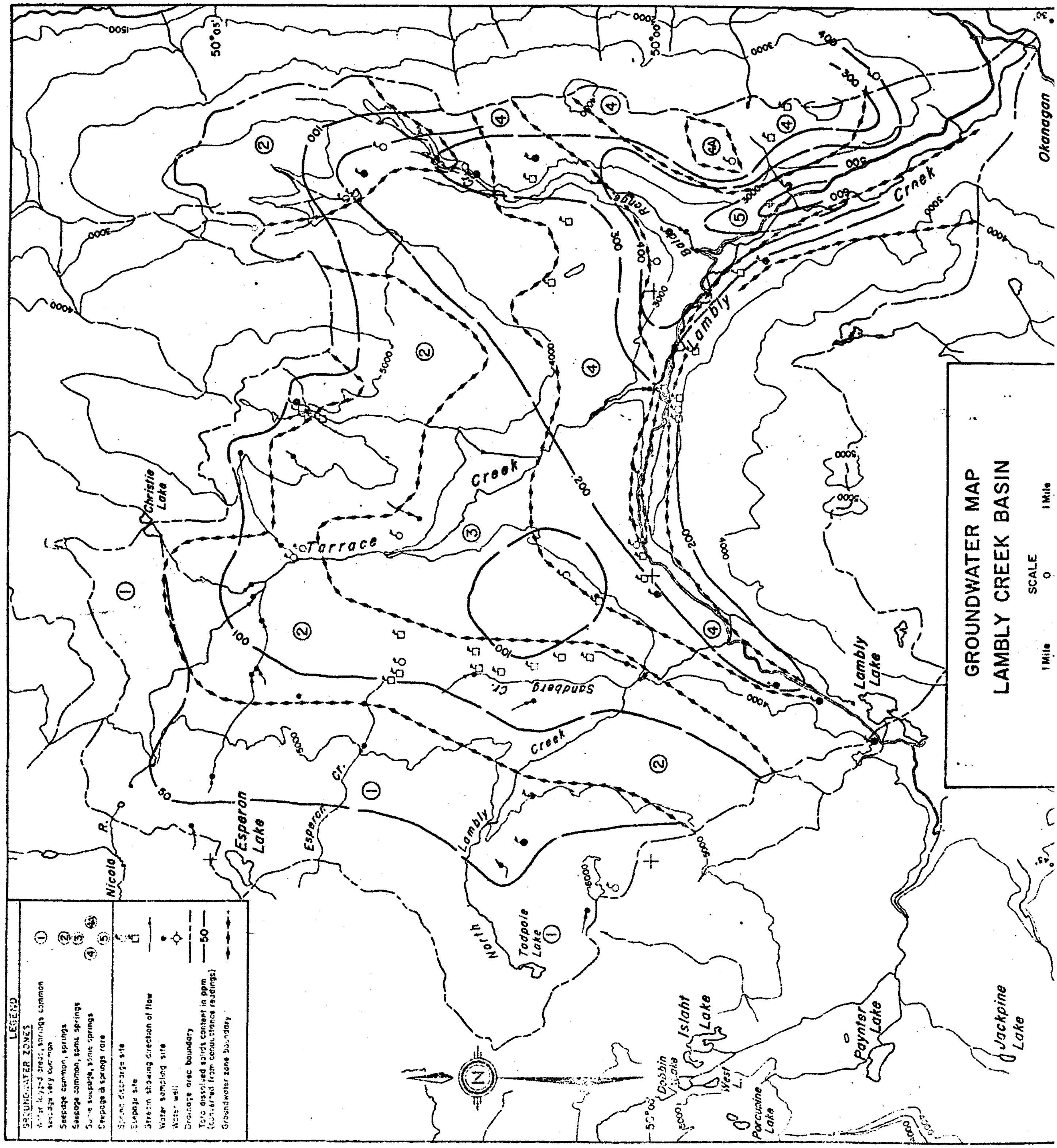
The surficial geology (Figure 16.12) most of which has been mapped by R.J. Fulton (1969) consists mainly of till, an unsorted mixture of sand, silt, clay and boulders, commonly less than 25 feet thick. Fluvial deposits of sand and gravel with locally some silt, are commonly found flanking the steep valley faces of Lambly Creek.

16.5.4 Hydrogeology

a) Groundwater Mapping

As access roads are well distributed in this sub-basin, it was possible to make observations concerning groundwater features across much of the area. Numerous trips were made into the basin between early summer and fall, permitting observations which give an indication of influence of seasonal variations in temperature and precipitation upon rates of groundwater discharge and storage. Plotting of basic data and its subsequent synthesis resulted in diversion of the basin into several groundwater zones (Figure 16.11). At the highest levels from 4,500 feet to 4,800 feet, zone 1, a zone of thick snow accumulation, spring and summer melting gives rise to water-logged areas, or terrain with many springs and often very widespread seepage. Zone 2, in an elevation range of about 4,000 feet to 4,400 feet is characterized by fewer springs and somewhat less seepage. Zones 1 and 2, the source and near source areas for creeks give rise to permanent runoff and most of the groundwater discharge. These are zones of considerable water surplus. Spring discharges are commonly less than 2 imperial gallons per minute and many of the spring discharges do not become part of the main streamflow.

There appears to be considerable groundwater and surface water that is lost by evapotranspiration so that much of the precipitation is involved in a hydrologic cycle that is complete at these high levels. At successively lower elevations than zones 1 and 2, are zones 3, 4 and 5 with an ever decreasing number of spring discharge sites and seepage features.



GROUNDWATER MAP
LAMBLY CREEK BASIN
SCALE
1 Mile
0
1 Mile
LEGEND
Okanagan
Lambly Creek
Bald Range
Christie Lake
Terrace Creek
Sandberg Cr.
Lambly Creek
Lambly Lake
Esperon Lake
Esperon Cr.
Nicola R.
North Lambly
Tadpole Lake
Islaht Lake
Paynter Lake
Jackpine Lake
Dobbin Lake
West L.
Porcupine Lake
50°05'
50°00'

FIGURE 16-12

Locality 4A was so separated because of the rare occurrence of a permanent, nearly constant flowing spring of about 2 igpm (imperial gallons per minute). This spring observed many times during the field season, showed no noticeable drop in yield in contrast to most springs many of which went dry or nearly dry. Occurring on a steep slope without a particularly large catchment area, its west-facing aspect combined with possible high storage may account for its steady flow.

b) Water Quantity

There is no information available concerning permeability of the bedrock nor surficial deposits for Lambly Creek sub-basin.

Recourse therefore must be made to texts discussing data on the same rock types occurring elsewhere. For information on granitic and basalt rock types, reference is made to Meinzer (1923). Granitic type rocks are generally poor water bearers and when encountered at several hundred feet, are almost devoid of water. Mater is obtained from joint openings which may be expected to close rapidly with depth. The vast majority of wells producing water from granitic rock are less than 300 feet deep, most of the water supply coming from depths of less than 100 feet. Well yields range from 2 to 25 igpm and average about 10 igpm.

Well yeilds and spring flow from basalts prove this rock type to be a good aquifer in the United States. "The water occurs in large joint openings and other cavities. This rock is so generally traversed by large openings that it takes in surface water very readily", (Meinzer, 1923). Frequently, well yields up to 100 igpm may be anticipated. In areas favourable to high well yield, similarly high spring flows are to be expected and do, in fact, occur.

Within the writer's limited field observations, no evidence was found of spring flow from bedrock sources. This may be taken to suggest generally low permeability and low water yield of the bedrock in the basin. Information confirming generally low well yields from bedrock sources within the Okanagan, is given by Halstead, E.C. (1969) and from an observation well drilled into volcanic rocks in Pearson Creek sub-basin in 1970 and supervised by the Groundwater Division. Both programs, examples, from wells to as deep as 270 feet show well yields from several small fractures to be in the range of 1 to less than 10 igpm.

With regard to the surficial deposits these are primarily till, and again are predominantly low permeability materials. The common occurrence concerning groundwater discharge is mainly of spring seepage with some spring flows less than 2 igpm. The fact that there is noticeable decrease in flow, some of which cease entirely and of considerable decreases in size of spring seepage areas from spring to fall suggests generally low groundwater flow from the surficial deposits. This very noticeable decrease in groundwater discharge is evidence of the dependence of storage areas upon replenishment by snowmelt and of the limited storage capacities of the material from which discharge takes place.

As the objective of the sub-basin studies was to assess, even on a qualitative basis, the possible importance of the groundwater component to stream flow. It is believed that most of the groundwater to stream flow originates in the source areas of zone 1. The groundwater is derived mainly from the surficial deposits and possibly from shallow depths In the bedrock. Almost all of the water supply leaving the basin is considered measured by runoff gauges and losses beneath and around gauging sites Is thought to be minor.

c) Water Quality

Numerous conductivity measurements of springs and stream flow were plotted as parts per million (conversion factor 1 ppm = 1.56 x 10^6 mho/cm at 25°C Todd, 1959, p. 328). The plotted results when contoured show a steadily increasing mineral content with increasing flow path. Very high elevation areas, areas of groundwater recharge, have waters low in total dissolved solids and low elevation areas, discharge areas have waters higher in total-dissolved solids. Both surface streams and groundwater (springs) show the same trend. The Increase In mineralization is commonly small, further suggesting that groundwater contributions to runoff are small.

16.6 HYDROGEOLOGY OF GREATA CREEK SUB-BASIN

16.6.1 Introduction

a) Methods of Investigation

As sub-basins are virtually unsettled, any study of the groundwater regime must first be directed towards qualitative reconnaissance studies of natural phenomena. This involved field mapping of groundwater features such as springs and seepage sites in relation to topography and geology. Air photos were used to supplement field studies.

16.6.2 Geography

a) General Comments

Greata Creek sub-basin lies between lines of lattitude 49°4' and 49°49' north and meridians of logitude 119°51' and 120°0' west. It has a total area of about 12 square miles. This sub-basin is closely comparable with the Lambly Creek sub-basin where Lambly Creek flows within its upper and central portions, In terms of topography, direction of stream flow and aspect. Greata Creek flows from southwest to northeast and turns east to flow into Peachland Creek. The

basin has an east-facing aspect (Figure 16.13).

16.6.3 Geology

a) General Comments

The bedrock geology as shown in Figure 16.13 taken from Geodetic Survey of Canada Map 538A, Kettle River (west half), geology by Cairnes, C.E. (1936) consists primarily of granodiorite, diorite and quartz diorite rock types.

The surficial geology (Figure 16.14) is mainly till, commonly quite thin across much of the area with sand and gravel deposits flanking and underlying Greata Creek. The thickness of these deposits is estimated to be up to 50 feet thick.

16.6.4 Hydrogeology

As Greata Creek covers a very small area and was mapped during a short time interval in the summer after the influences of snowmelt had largely disappeared, it was possible to observe only a limited number of groundwater features. This basin lies at an elevation range equivalent to zones 3 and 4 of Lambly Creek sub-basin and may earlier in the year exhibit more numerous sites of seepage and spring discharge. Because of the time of year at which this basin was mapped, its more southerly location, and the small number of groundwater discharge points actually observed, the basin zones are classified as similar

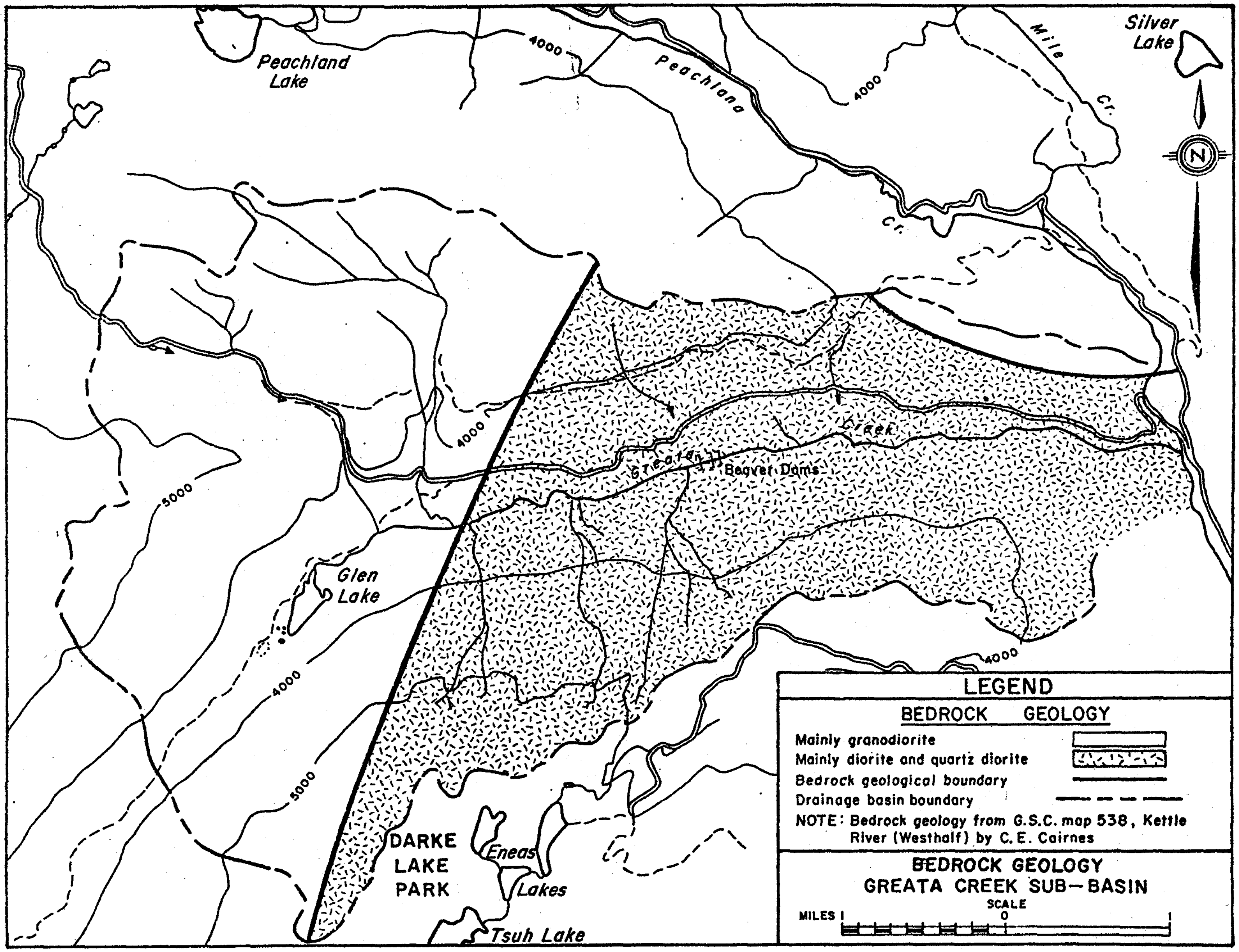

Peachland Lake
Peachland
Cr.
4000
Mile Cr.
Silver Lake
N
Creek
Greata
Beaver Dams
5000
Glen Lake
4000
5000
DARKE LAKE PARK
Eneas Lakes
Tsuh Lake
LEGEND
BEDROCK GEOLOGY
Mainly granodiorite
Mainly diorite and quartz diorite
Bedrock geological boundary
Drainage basin boundary
NOTE: Bedrock geology from G.S.C. map 538, Kettle River (Westhalf) by C.E. Cairnes
BEDROCK GEOLOGY
GREATA CREEK SUB-BASIN
SCALE
MILES 1 0 1

FIGURE 16-13

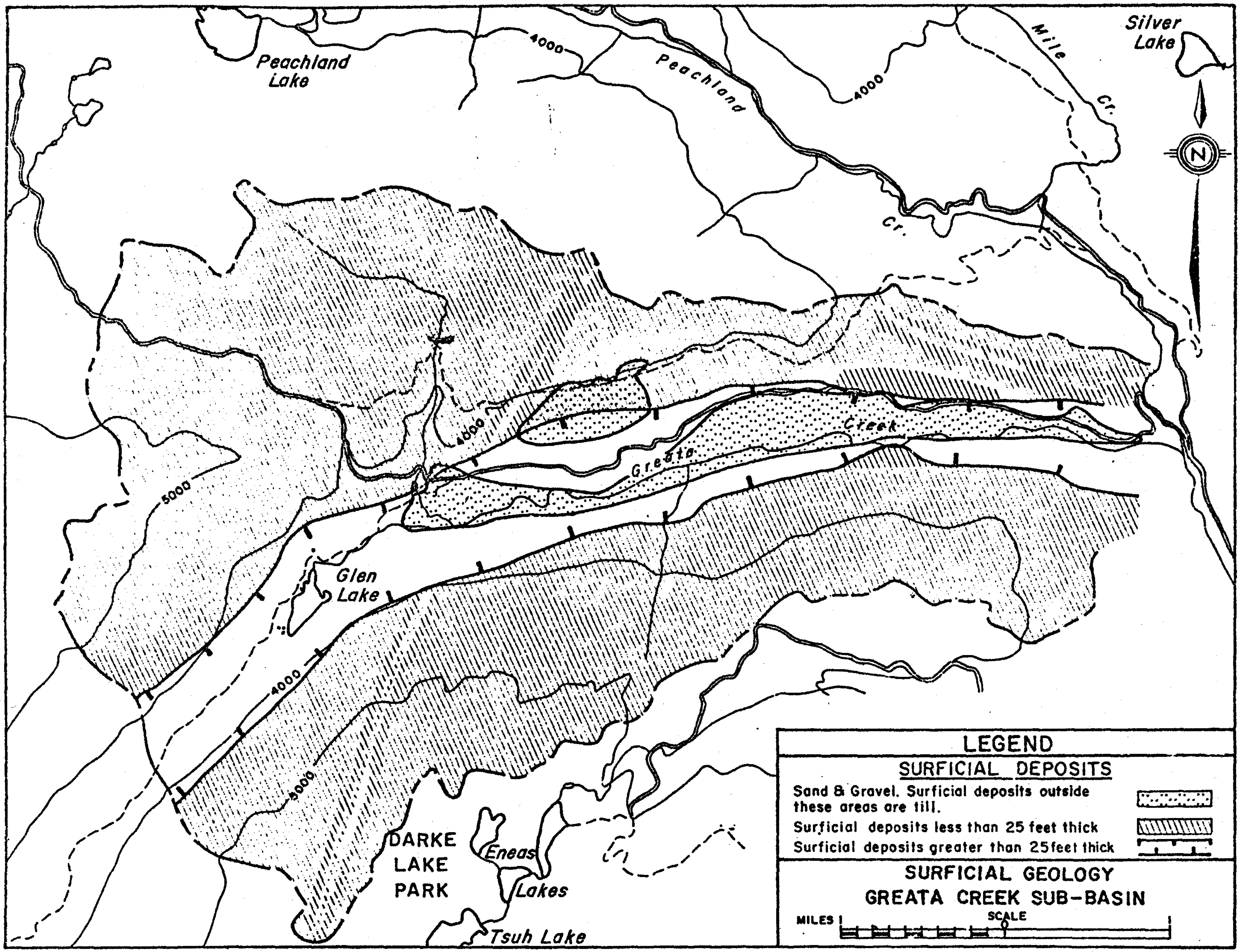

Peachland Lake
Peachland
Silver Lake
Mile Cr.
Cr.
4000
5000
Greata Creek
Glen Lake
DARKE LAKE PARK
Eneas Lakes
Tsuh Lake
N
LEGEND
SURFICIAL DEPOSITS
Sand & Gravel. Surficial deposits outside these areas are till.
Surficial deposits less than 25 feet thick
Surficial deposits greater than 25 feet thick
SURFICIAL GEOLOGY
GREATA CREEK SUB-BASIN
MILES
SCALE

FIGURE 16-14

to zones 4 and 5 of Lambly Creek.

Increases in stream flows are generally associated with additional tributary creeks entering the main creek. However, an intermittently appearing stream, the most northwesterly tributary creek, revealed an overall increase in flow, some of which might possibly be attributed to groundwater discharge. However, as in the case of Lambly Creek, there is little evidence to suggest more than minor contributions from groundwater to the increase in stream flow. Again there was some small increase in total mineralization of the streams with increased flow pathe (Figure 16.15) supporting the fact that some increment from groundwater was made to stream flow.

16.6.5 Conclusions

Conclusions drawn from the study of the two foregoing sub-basins are that most of the discharge of water from the basins is measured as runoff. The amount of groundwater flow which goes unmeasured is probably very small and would form a very small percentage of the total runoff of both basins.

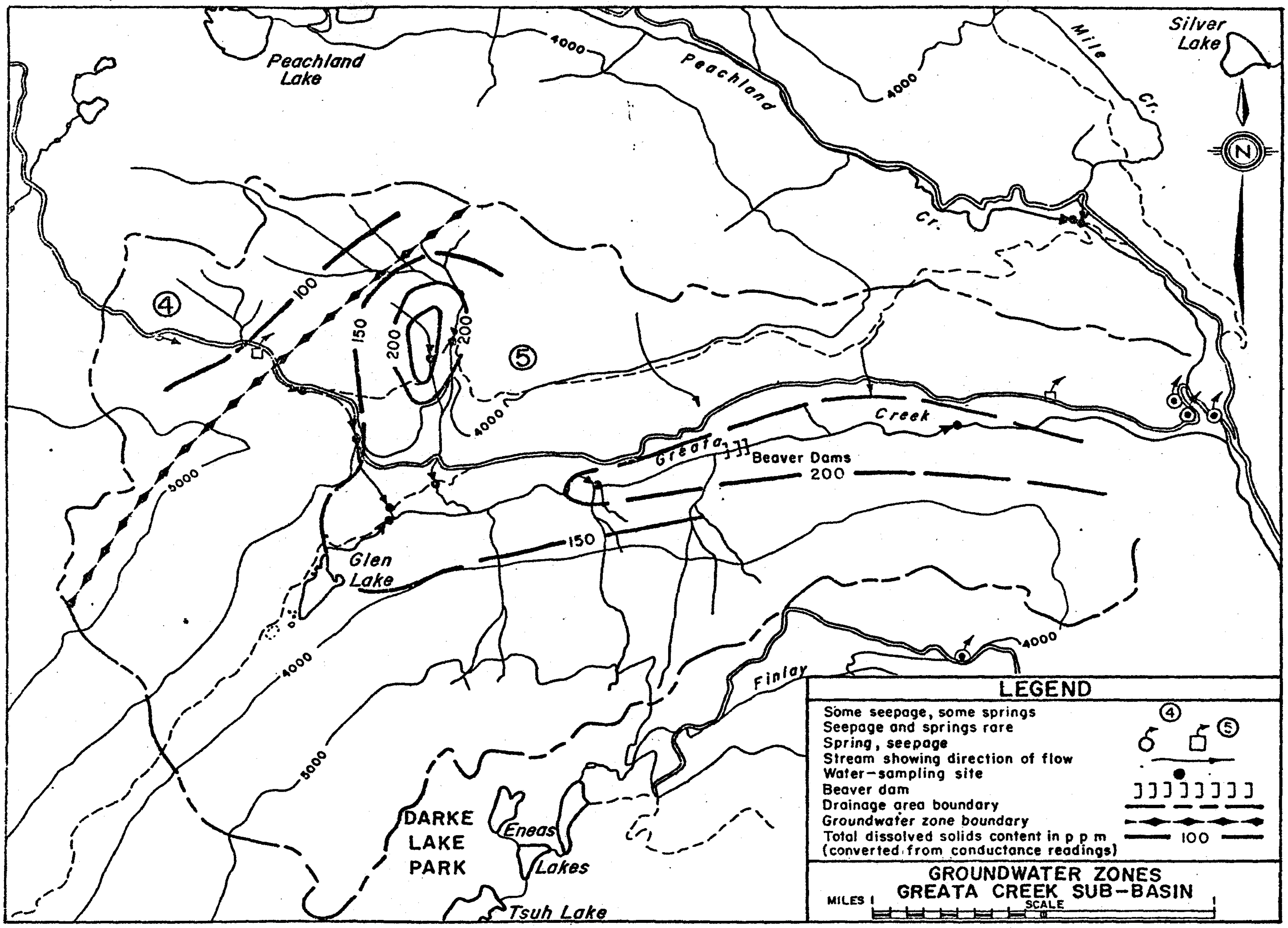

Peachland Lake
Silver Lake
Peachland
Mile
Cr.
Cr.
N
4000
100
150
200
200
200
4
5
Greata
Creek
Beaver Dams
200
150
Glen Lake
5000
4000
5000
Finlay
4000
DARKE LAKE PARK
Eneas Lakes
Tsuh Lake
LEGEND
Some seepage, some springs
Seepage and springs rare
Spring, seepage
Stream showing direction of flow
Water-sampling site
Beaver dam
Drainage area boundary
Groundwater zone boundary
Total dissolved solids content in p p m
(converted from conductance readings)
100
GROUNDWATER ZONES
GREATA CREEK SUB-BASIN
MILES
SCALE

FIGURE 16.15