Province of British Columbia

Ministry of Environment
WATER MANAGEMENT BRANCH

MEMORANDUM

To: A.P. Kohut
Senior Geological Engineer
Groundwater Section
Water Management Branch

Date: February 1, 1983

File: 92 P/13(1)

Re: Kokanee Bay, Lac La Hache Groundwater Contamination

Introduction

Kokanee Bay of Lac La Hache has been identified by the Cariboo Regional Fisheries Biologist as the area where the majority of the kokanee in the lake spawn. At present, there are about a dozen domestic septic tank installations situated within 500 feet of the shore of Kokanee Bay. A proposed development located between 1000 and 2000 feet from the shore of the bay could increase the number of septic tank sites in the area to 49.

In a memorandum to J.C. Foweraker, Head of the Groundwater Section, Mr. A.O. Stephens, the Cariboo Regional Waste Manager, has requested comments on the potential for adverse effects on the surface water quality in the spawning grounds area of Kokanee Bay resulting from possible groundwater transport of nutrients from nearby septic tank effluent sources. The following report is based on an office study of aerial photographs, geologic maps, well records, seepage meter data, water quality data and previous reports by other branches.

In order to evaluate the potential effects that the nutrients (particularly nitrogen and phosphorous) generated from existing and proposed residential septic tank systems may have on the quality of water in the spawning grounds, the following factors have been considered:

(1) the hydrogeologic setting
(2) the amount of groundwater flow
(3) the amount of nutrient loading and dilution effects
(4) other sources of possible nutrient input
(5) an analysis of water quality test results

1. Hydrogeologic Setting

According to H.W. Tipper (1971), Lac Lac Hache was once occupied by a meltwater channel. Forbes Creek, which flows into Lac La Hache appears to have been a minor tributary channel. Tipper (1971) has also identified a minor esker complex associated with this tributary channel. Figure 1 shows the general boundaries of these channels and the distribution of surficial sediments in the area according to Valentine and Schori (1980).

In order to determine the subsurface conditions in the area, data from well records (Table 1) of known domestic wells and springs in the area (see Figure 2 for locations) have been analyzed. As a result, four hydrogeologic cross-sections have been constructed as shown in Figures 3 and 4. Based on these hydrogeologic sections and the surficial geology of the area, the approximate extent of the main aquifer underlying the study area has been outlined as shown in Figure 5. This main aquifer lies along the east side of Forbes Creek and is unconfined; approximately 2,000 feet in width by approximately 10 feet in saturated thickness; and is comprised of glaciofluvial sands and gravels (see Figure 3). According to the well log data, the depth to the water table has been estimated between 5 feet and 20 feet below ground level. Figure 5 also shows the apparent direction of groundwater flow in the area based on the limited water level data and regional topographic considerations.

The main source of recharge to this aquifer appears to be Forbes Creek. Other possible sources of recharge include direct precipitation over the aquifer and seepage from areas upslope, especially northeast of the study area.

2. <u>Amount of Groundwater Flow</u>

The theoretical amount of groundwater flowing through the aquifer can be estimated using the standard Darcy formula for fluid flow through a porous media (viz. $Q = KiA$). Essentially, Darcy's Law relates the discharge Q in gallons per minute to the product of the hydraulic conductivity K, in gallons per day per square feet, the hydralic gradient i (dimensionless), and the cross-sectional area A, of the aquifer normal to the flow direction, in square feet. Consequently, assuming a range of hydraulic conductivity for the glacial (esker) deposits of between about 200 gpd/sq. ft. and 2700 gpd/sq. ft. (based on Terzaghi and Peck, 1967); and a gradient i, of approximately 0.03 (based on Figure 4); and an A of about 20,000 sq. ft. (i.e., 2,000 feet wide x estimated average aquifer thickness of 10 feet), then the theoretical discharge Q, flowing through the width of the aquifer towards Kokanee Bay is between about 90 USgpm and 1100 USgpm. According to Freeze and Cherry (1979), the porosity of sand and gravel can range between 25% and 40%. Therefore, assuming a conservative porosity value of 30% (i.e., 0.3), the theoretical average linear interstitial groundwater velocity may range between 3 ft. per day and 40 ft. per day.

During the summer of 1982, Waste Management staff of Williams Lake, installed several groundwater seepage meters at various sites along the spawning grounds (see Figure 5), to determine the actual amount of groundwater seeping into the spawning grounds. These meters were installed approximately 10 feet from the shoreline and in about 3 feet of water. From the data collected, the average hydraulic conductivity was calculated to be in the order of 0.1 gpd/sq. ft. The estimated discharge, assuming a hydraulic gradient of 0.03 and an estimated cross-sectional aquifer area of 20,000 square feet, is less than 1 USgpm.

It is evident that the field results are significantly less than the theoretical minimum expected (i.e., 90 USgpm). In view of the regional groundwater conditions and permeable nature of the aquifer materials, it appears that the field results are not representative of the actual groundwater flow conditions. This discrepancy may be due to several possible reasons, including:

(a) improper functioning of the seepage meters,
(b) the presence of a local underlying lacustrine clay or silt layer(s),
(c) improper location of meters, thereby not being able to intercept the main component of groundwater flow

3. Amount of Nutrient Loading and Dilution Effects

According to Dale Wetter of the Waste Management Branch in Victoria (pers. comm.), the average septic tank's effluent has a total nitrogen concentration of about 30 mg/L and a total phosphorous concentration of about 8 mg/L. These figures are in close agreement with the results determined by Oldham and Kennedy (1973) of analyses of septic tank effluent in the Okanagan Valley. Results of a field survey by Williams Lake Waste Management staff, of the residential and tourist-oriented establishments in the Kokanee Bay area indicate that there are 12 septic tank disposal sites that can potentially affect the quality of groundwater flowing towards Kokanee Bay. Direct measurements of the amount of wastewater leaving the septic tanks in the area have not been made. Consequently, assuming a water consumption rate of 80 USgpd per capita and 3.5 persons per site, the estimated potential peak sewage flow from the existing 12 septic tank sites is 3,360 gallons per day (i.e., 15,000 litres per day). Using the previously mentioned figures for nitrogen and phosphorous loadings per septic tank site, the total estimated potential peak nitrogen loading is 450 grams per day and the total estimated potential peak phosphorous loading is 120 grams per day.

During the down-gradient migration of these nutrients towards Kokanee Bay via the groundwater flow system, the concentration of nitrogen and phosphorous will be redueed by dilution. Assuming that the concentrations of total nitrogen and phosphorous are unchanged upon reaching the groundwater table (i.e., no sorption by the soil) and subsequent mixing occurs throughout the entire saturated cross-section of the aquifer, then the estimated theoretical concentration of total-N and total-P in the groundwater that may be entering Kokanee Bay is between 0.08 mg/L and 0.74 mg/L for total-N and between 0.02 mg/L and 0.20 mg/L for total-P. The above simplication of the theoretical situation is given to illustrate the magnitude of nutrient levels that may occur. In actual fact, the magnitude of nutrient levels that may occur in the groundwater entering the spawning grounds at Kokanee Bay will depend upon a number of factors including:

(a) the actual quantity of groundwater flow (Q) occurring through the section of aquifer (A) that is contaminated with effluent. If Q is greater, more dilution occurs and the nutrient concentrations decrease down-groundwater gradient.

(b) the actual amount and concentration of nutrient loading.

(c) the thickness of the saturated aquifer that is contaminated by the effluent. According to Dudley and Stephenson (1973), studies have shown that the highest concentrations of nutrients occur in he upper several feet of saturated aquifer. They further state that mixing of effluent and groundwater is limited to the upper 5 feet of the aquifer at close distances to the absorption field.

(d) the hydraulic gradient (i). Shallower gradients reduce (Q), thereby reducing the dilution effects. However, with shallower gradients, the groundwater velocity decreases. As a result contaminated water is retained in the soil longer, thus allowing more adsorption and precipitation of dissolved nutrient constituents.

(e) The hydraulic conductivity (K). The larger the hydraulic conductivity, the greater the (Q), and therefore the more effective dilution becomes. On the other hand, the greater the (K), the greater the velocity will be, therefore reducing the amount of time available for adsorption and precipitation.

(f) the chemical/biochemical reactions with the underlying unsaturated and saturated soils. In sandy and gravelly materials phosphates may easily be transported down-gradient by groundwater. However, if there are small amounts of clay minerals, iron oxides, aluminum oxides or limestone present, these materials may fix the phosphates in the soil thereby decreasing the phosphate content down-groundwater gradient.

(g) the distance of effluent transport. The greater the distance the septic tank system is from a water body, the greater the potential for phosphorous removal by the underlying soils, and effluent dilution.

(h) the chemical composition of the lake sediments. According to Jones and Lee (1977), the interactions between the sediments in the lake and the nutrients entering the lake via groundwater flow (could) tend to convert both nitrogen and phosphorous to forms unavailable for stimulation of algal growth.

The proposed development located north of the highway and straddling Forbes Creek would involve the construction of approximately 37 septic tank effluent disposal systems. As shown in Figure 5, the apparent direction of groundwater flow in the area is predominantly from the development area towards the spawning grounds. Therefore, only at those sites located east of Forbes Creek (i.e., within the main aquifer) would the nutrient loading from septic tank effluent potentially affect the water quality of the groundwater emerging in the spawning grounds. According to the development plans, there would be an increase of about 20 septic disposal sites within the boundaries of the aquifer. Assuming that the concentrations of total nitrogen and phosphorous are unchanged upon reaching the groundwater table and subsequent mixing occurs within the entire cross-section of the aquifer, then the <u>theoretical</u> maximum increase in the total Nitrogen and total Phosphorous concentrations reaching Kokanee Bay (assuming no sorportion by aquifer materials) is estimated at 1.50 mg/L for total Nitrogen and 0.40 mg/L for total Phosphorous. In reality, the maximum concentrations expected would be less depending upon such factors as adsorption, the depth to the water table, amount and velocity of groundwater flow, distance between the septic tank systems and Kokanee Bay, etc.

4. Other Sources of Possible Nutrient Input

The use of fertilizers on lawns and gardens can provide another possible source of nutrients into the groundwater system.

Nitrogen and phosphorous in groundwater can also occur in nature. In the study area, evidence of background levels of nitrogen of organic origin has been reported in the groundwater emerging from Spring No. 14, located up-gradient of any known development. A water quality analysis of a sample of the spring water showed that the total nitrogen of 0.36 mg/L concentration was in the form of organic nitrogen. Background levels of phosphorous may also be present in the groundwater due to the volcanic nature of the underlying bedrock. Groundwaters in contact with the volcanic bedrock may pick up natural phosphorous which would be carried down-gradient by groundwater towards the area of the septic fields and thereby possibly contribute to the total phosphorous content of the groundwater regime. Groundwater quality testing in areas upslope of the existing septic fields would be required to better determine possible contributions from natural sources.

5. Analysis of Water Quality Test Results

Samples of groundwater were collected in the summer of 1982, from four wells, two springs and five seepage meters. The values of the various chemical and physical parameters measured are presented in Table 2. The pH values of the samples ranged from 7.4 to 8.3. Values in this order of magnitude are considered normal for groundwater and would not be expected to cause any water quality problems.

Specific conductance values ranged from 670 to 760 μmhos/cm. Since background levels of specific conductance of groundwater samples in the area have not been measured, it is not known to what extent the septic tank effluents are contributing to the total amounts of salts in groundwater solution. A measure of the specific conductance of Forbes Creek at the mouth, indicated a value of 393 μmhos/cm. A comparison between this value and the values reported from groundwater samples indicates that there may be some contamination of the groundwater by septic tank effluent.

The total Nitrogen concentrations range between 0.31 and 7.00 mg/L. Concentrations of this magnitude are not considered excessive for water supply purposes. Of the eleven sampling sites, five sites (Well No. 10, Spring No. 13, Seepage Meters 1, 6 and 7) had reported total nitrogen concentrations greater than the theoretical maximum anticipated. This implies that these sites are likely situated close to the sources of the nutrients. In the case of Well No. 10 and Spring No. 13, (both sites located near the shoreline and downslope of existing residential development) the predominant forms of nitrogen were found to be ammonia and nitrite-nitrate, respectively. Since effluents from septic tanks systems normally contain large quantities of nitrogen in the form of ammonia (among other constituents), the nitrogen concentrations found in Well No. 10 and Spring No. 13 are most likely derived from nearby septic tank effluent sources. In the case of seepage meters 1, 6 and 7, the predominant form of nitrogen was found to be organic nitrogen. The ammonia-nitrogen concentrations in Seepage meters 1 and 7 were also reported relatively high (i.e., 0.668 and 0.220 mg/L as compared to less than 0.007 mg/L for the other seepage meter samples). Since organic nitrogen is also a major constituent of septic tank effluent then its presence along with significant concentrations of ammonia-nitrogen, suggests that the nitrogen concentrations found in samples of the groundwater from seepage meters 1 and 7 are most likely derived from nearby septic tank effluent sources.

The absence of any significant amount of ammonia-nitrogen in the sample of groundwater from seepage meter 6 suggests that the nitrogen concentration at this site (being predominantly in the organic form) may be derived from another source of nutrient, other than septic tank effluent).

The total phosphorous values ranged between 0.009 mg/L and 0.411 mg/L. Of the wells and springs sampled, the phosphorous was found to be generally in the soluble orthophosphate form. The phosphorous concentration of the groundwater reported in Well No. 10 (0.411 mg/L) exceeded the theoretical maximum (0.20 mg/L) anticipated. This high phosphorous value suggests a nearby septic tank effluent source. Since background levels of phosphorous in the area are not known, it is not known how much of the phosphorous present in the groundwater can be attributed to septic tank effluent sources. However, due to the permeable nature of the underlying sand and gravel sediments which have relatively low adsorptive capacity for phosphorous, and the proximity of the sampling sites to septic tank systems, it is not improbable that a significant percentage of the phosphorous concentration reported is derived from septic tank effluent sources. Results of nutrient analyses on samples of lake water taken by Terrestrial Studies Branch staff in August 1981, indicated that the total phosphate concentration in the spawning area of Kokanee Bay was 0.013 mg/L. Results of water quality analyses on samples of groundwater taken from the seepage meters located in the spawning area showed the concentration of total phosphorous to range between 0.048 mg/L and 0.188 mg/L. This difference in concentrations suggests the source of phosphorous is up-gradient; most likely from the nearby septic tank effluent sources.

Conclusions and Recommendations

Groundwater is discharging into the Kokanee Bay area of Lac La Hache at an estimated rate of between 90 USgpm and 1100 USgpm and moving at an estimated average velocity of between 3 feet per day and 40 feet per day.

Based on an analysis of the available data, it is evident that septic tank effluent is contributing to nutrient loadings in the groundwater and surface water of the Kokanee Bay area. At present, it appears that there are 12 septic tank systems located within 500 feet of the spawning grounds. It is estimated that the concentration of Nitrogen and Phosphorous in the groundwater discharging into Kokanee Bay, as a result of the nutrient input from the above septic tank systems, is less than 0.78mg/L of total Nitrogen and less than 0.20 mg/L of total Phosphorous. Results of water quality analyses of samples of groundwater from wells, springs and groundwater seepage meters indicate that at some of the sites tested, the total Nitrogen and total Phosphorous concentrations exceed the theoretical estimates, suggesting nearby sources of nutrients.

The additional amount of nutrient gain to the groundwater discharging into Kokanee Bay that may be expected from septic tank effluent, as a result of the proposed development is estimated at less than 1.50 mg/L total Nitrogen and less than 0.40 mg/L total Phosphorous.

To obtain more accurate estimates of the groundwater flow in the area and the potential effects of the present shoreline develoment on the quality of groundwater emerging in Kokanee Bay, further field data regarding the direction and amount of groundwater flow; the type and distribution of underlying sediments; the amount of nutrients being applied to the groundwater system; and the quality of groundwater and surface water down gradient from the present development at different times of the year will be required. In order to obtain the above data, the following field program is recommended:

(1) a site investigation of the area to confirm geologic conditions;

(2) a survey of the residents utilizing septic tank disposal systems, to determine water consumption rates so that a better estimate of the amount of sewage leaving the septic tank may be determined;

(3) the construction of four 6-inch diameter monitor wells located as shown in Figure 6. At three of the sites (identified with a letter "P", the wells would be drilled to anticipated depths of 40 feet or approximately 15 feet below the water table. In each of these wells, three 2-inch diameter plastic (PVC) piezometers would be installed at depths of about 5 feet, 10 feet and 15 feet below the water table. These piezometers would provide for the measurements of periodic (monthly) water levels; quarter-annual water quality sampling; and for the determination of aquifer permeability from slug tests. Water quality samples will be analyzed for nutrient constituents (Nitrogen and Phosphorous), pH, Specific Conductance, sodium, iron, aluminum, alkalinity and sulfate. The approximate cost of constructing these piezometers is estimated at $2,000 per site, excluding supervisory costs.

At the fourth site (identified with a letter "M"), the well would be drilled to an anticipated depth of 60 feet or until bedrock is encountered. Drilling of the well will provide an idea of the local stratigraphy and types of underlying soils. After completion of well construction, a pumping test will provide data for the determination of aquifer parameters (i.e., transmissivity, storativity, etc.). Initially the water level measured in the well will assist in the determination of the aquifer's hydraulic gradient. Subsequently, the water level would be monitored continuously for at least one year to determine the amount of groundwater level fluctuation with time. Continuous monitoring will require the installation of an automatic water level recorder. The well will also provide for periodic (semi-annual) water quality sampling, for the above-mentioned parameters. Results of the water quality analyses will be useful in ascertaining background levels of nutrient constituents. The approximate cost of completing this well and performing a 24-hour pumping test is estimated at $6,000, not including supervisory costs.

(4) the installation of six groundwater seepage meters located just off-shore of Kokanee Bay, as shown in Figure 6. The purpose of using these "meters" located closer to the shore than previously, is to determine the variation in the seepage flow rates in the area. These "meters" will also provide for quarter annual water quality sampling for the above-mentioned parameters. The cost of supplying and installing these "meters" would be minimal.

The above proposed field study would provide additional data necessary to better evaluate the present effects of septic tank effluent disposal in the Kokanee Bay area, and in evaluating the possible effects of the proposed development further upslope of the present shoreline development. It is recommended that the field monitoring be carried out for at least one year, after which the data collected can be analyzed and further comments and recommendations prepared.

Marc Zubel.

Marc Zubel
Geological Engineer
Groundwater Section
Water Management Branch
387-1115

MZ/dma

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(4) Oldham, W.K., Kennedy, G.F. 1973(?). "Influence of Septic Tank Effluent on Receiving Water Nutrient Gain from Groundwater." Canada British Columbia-Okanagan Basin Agreement, Preliminary Report No. 41.

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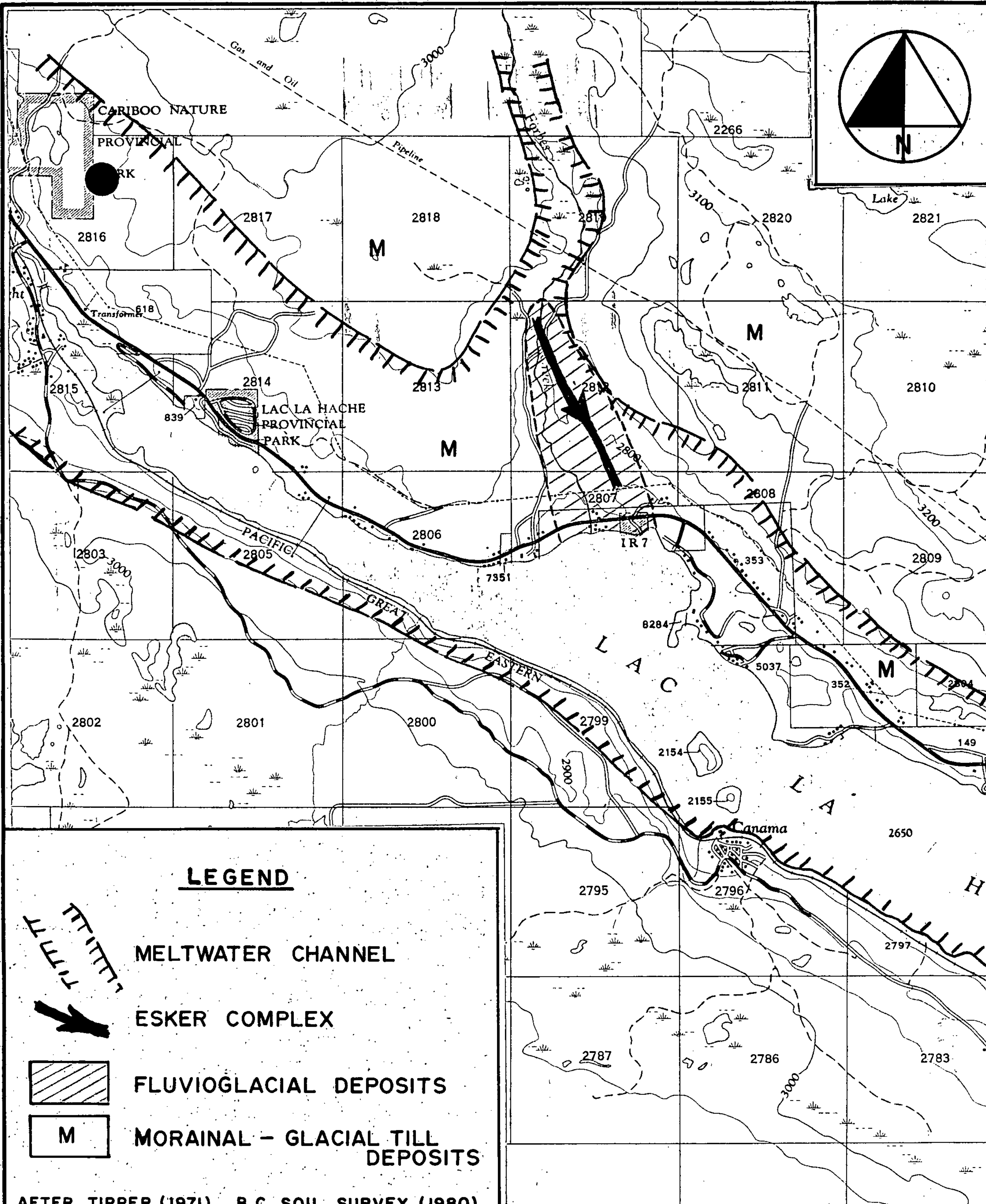
(8) Valentine, K.W.G., Schori, A. 1980. Soils of the Lac La Hache - Clinton Area, B.C." B.C. Soil Survey. Report No. 25, Agriculture, Canada.



Province of British Columbia
Ministry of Environment
WATER MANAGEMENT BRANCH

SURFICIAL GEOLOGY
of the
KOKANEE BAY AREA, LAC LA HACHE

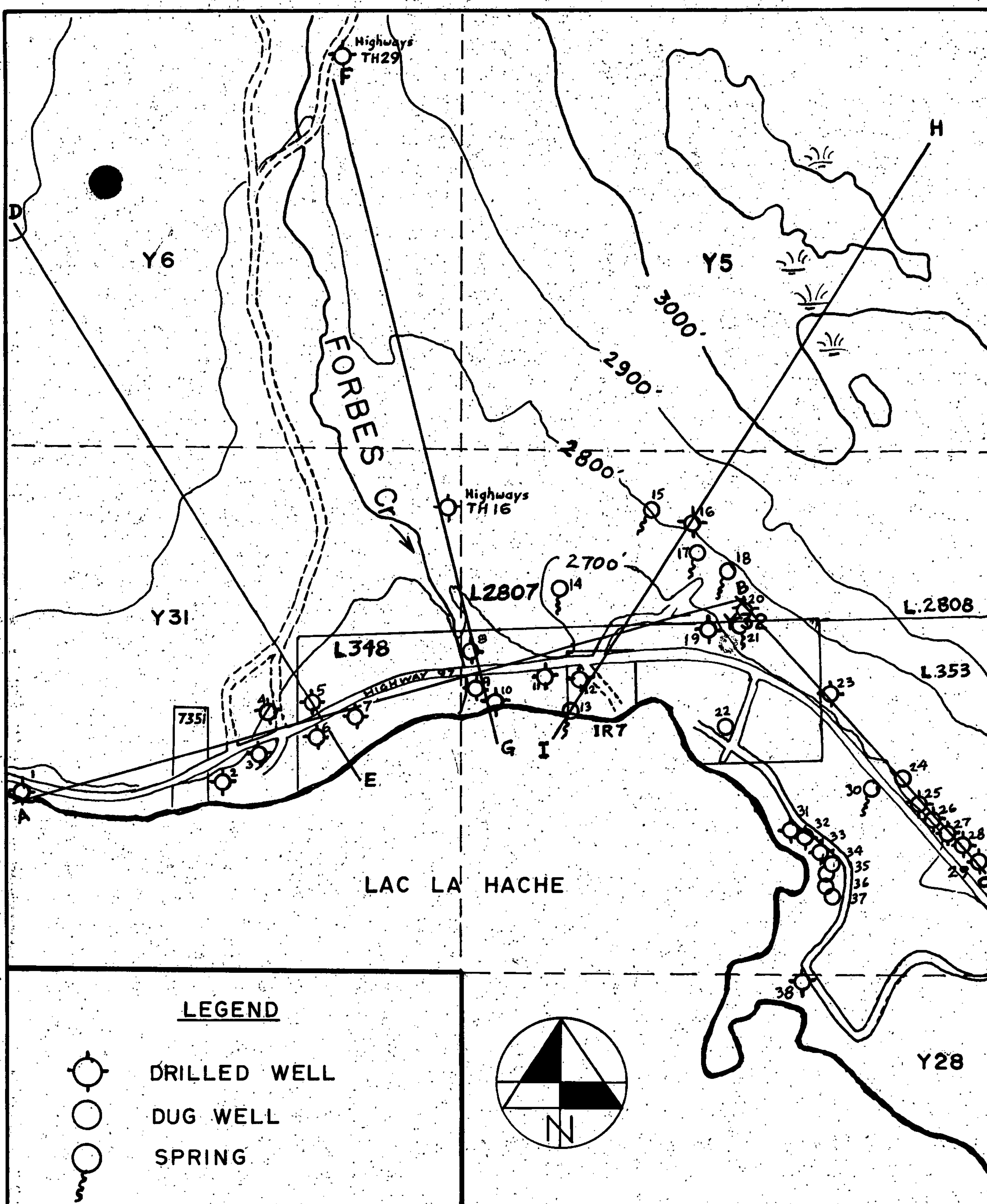
SCALE: VERT. N/A
HOR. 1: 50000

DATE NOV. 1982

M.Z. ENGINEER

FILE No. 92 P/13 DWG. No. FIGURE 1

BCIL 7673-M.E.



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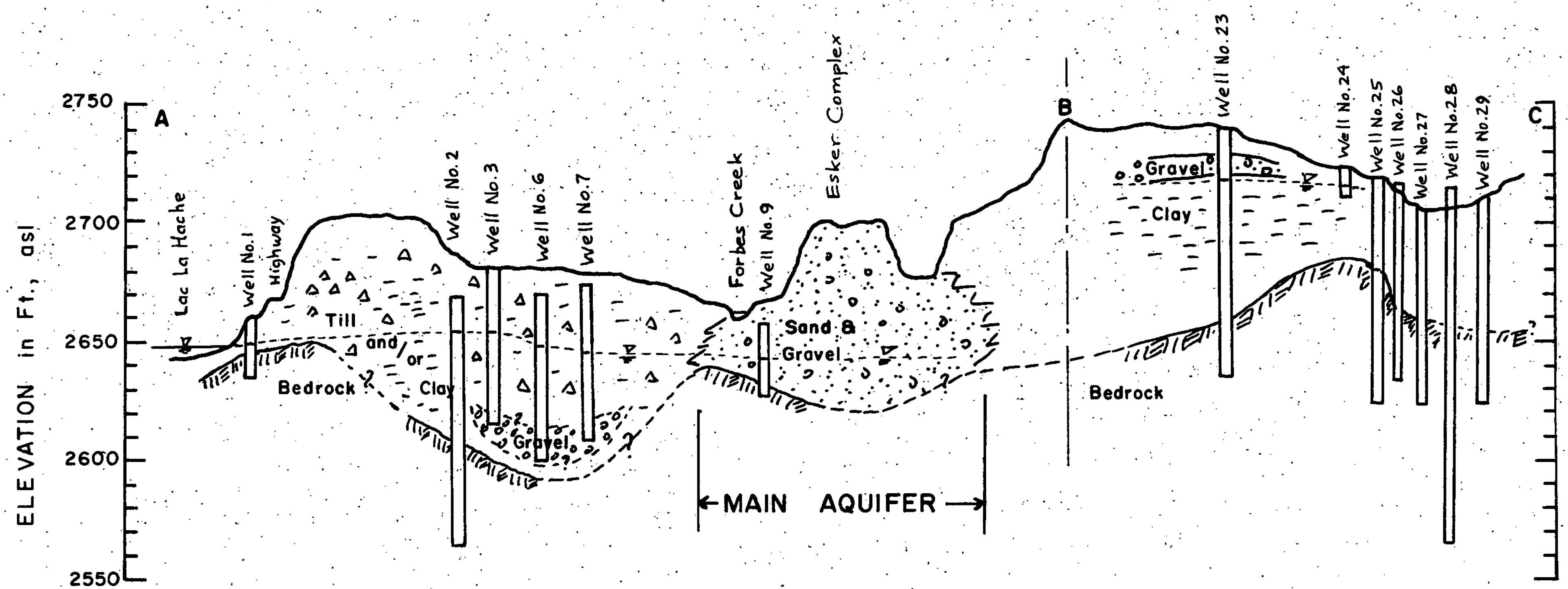
WATER MANAGEMENT BRANCH

LOCATION OF WELLS & SPRINGS
in the
KOKANEE BAY AREA, LAC LA HACHE

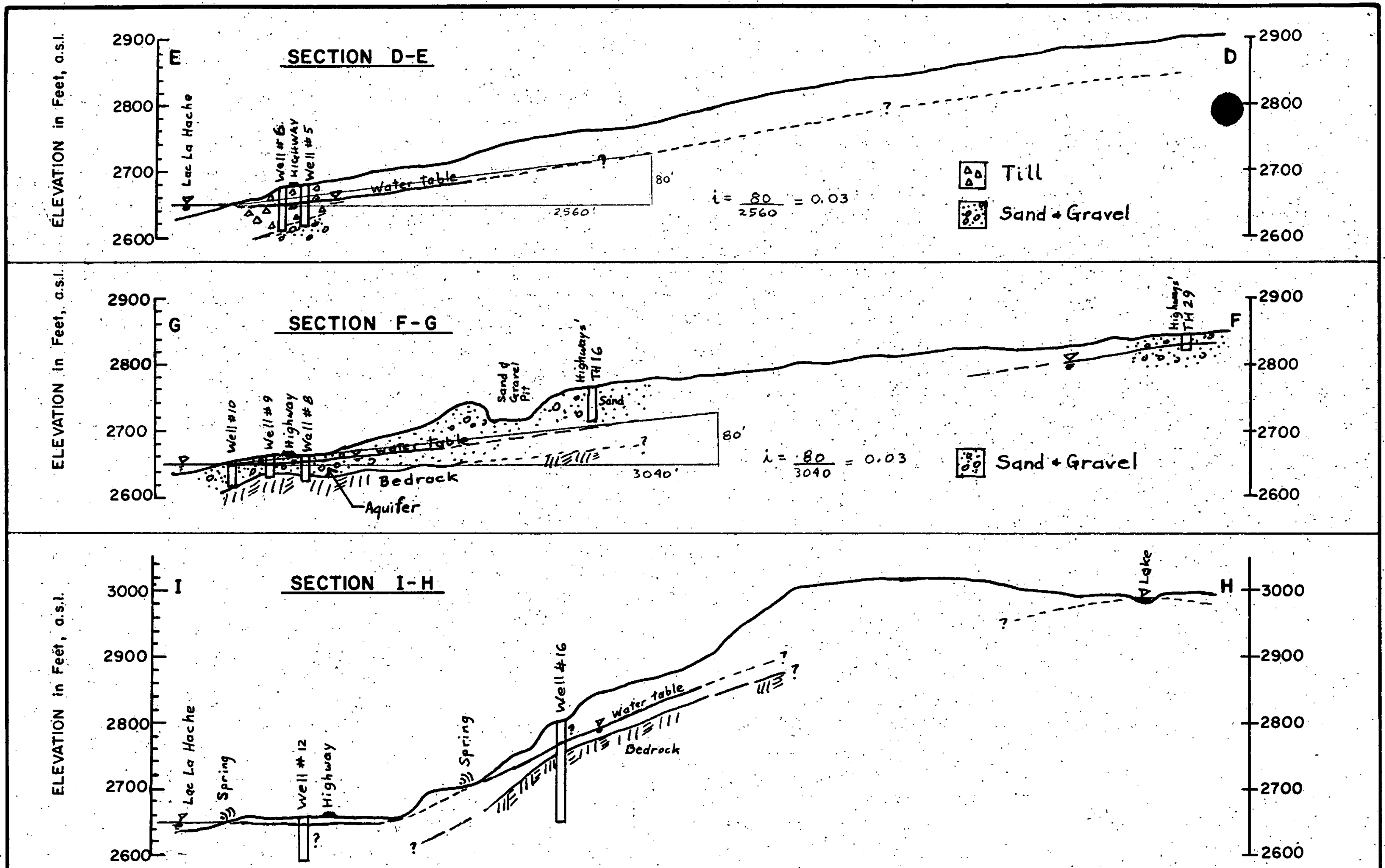
SCALE: VERT. N.A. HOR. 1" = 1320'	DATE NOV. 1982	M.Z. ENGINEER FILE No. 92 P/13 DWG. No. FIGURE 2

BCIL 7673-M.E.

SECTION A-B-C



Province of British Columbia Ministry of Environment WATER MANAGEMENT BRANCH	CROSS-SECTIONAL SKETCH KOKANEE BAY AREA, LAC LA HACHE	SCALE: VERT. as shown HOR. 1" = 1300' DATE NOV. 1982 M Z ENGINEER FILE No. 92 P/13 DWG. No. FIGURE 3



Province of British Columbia Ministry of Environment WATER MANAGEMENT BRANCH	CROSS - SECTIONS KOKANEE BAY AREA, LAC LA HACHE

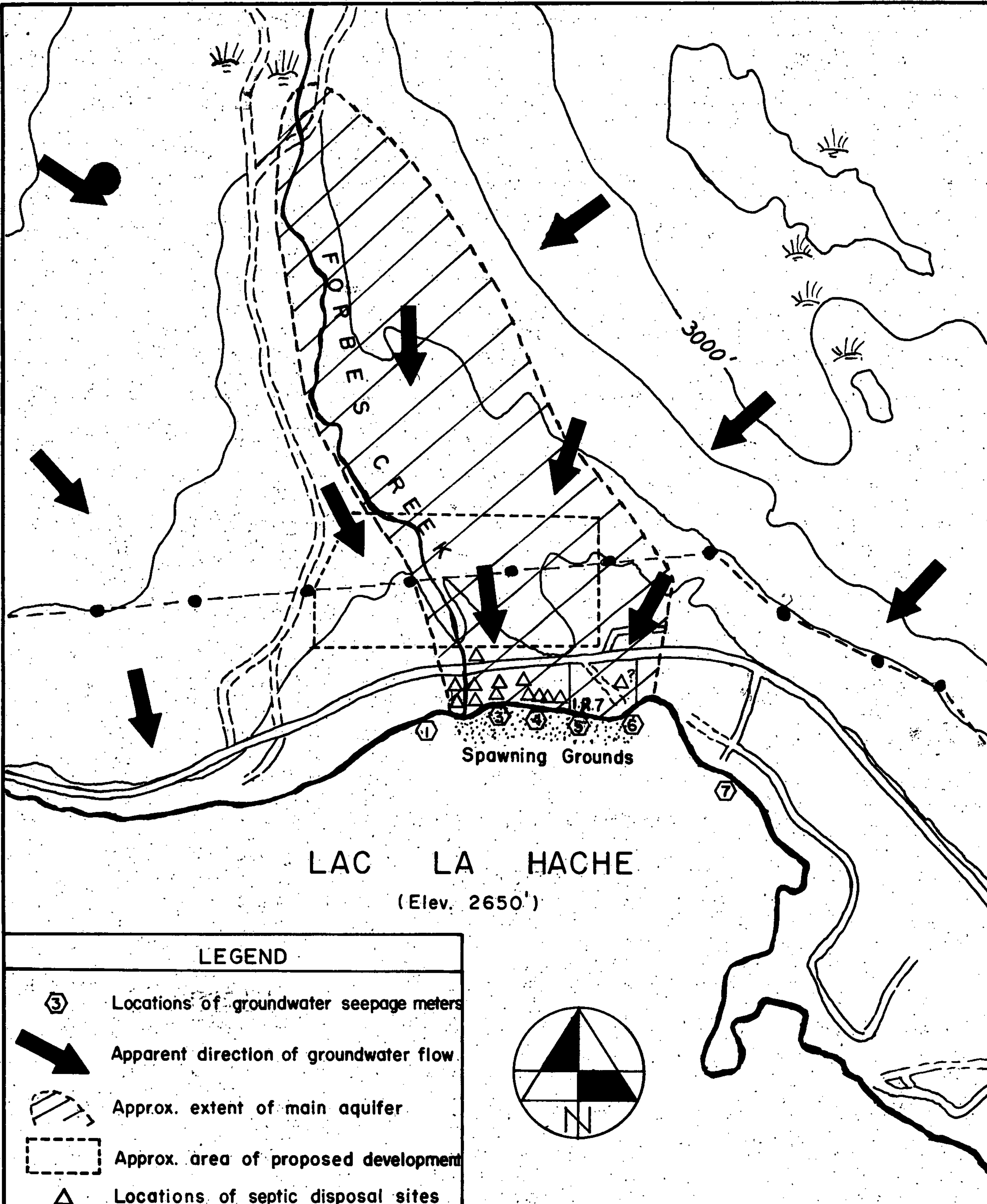
SCALE: VERT. 1" = 200'
HOR. 1" = 800'

DATE NOV. 1982

M.Z. ENGINEER

FILE No. 92 P/13 DWG. No. FIGURE 4

VANCAL 8570



Province of British Columbia
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WATER MANAGEMENT BRANCH

APPARENT DIRECTION OF GROUNDWATER FLOW
KOKANEE BAY AREA, LAC LA HACHE

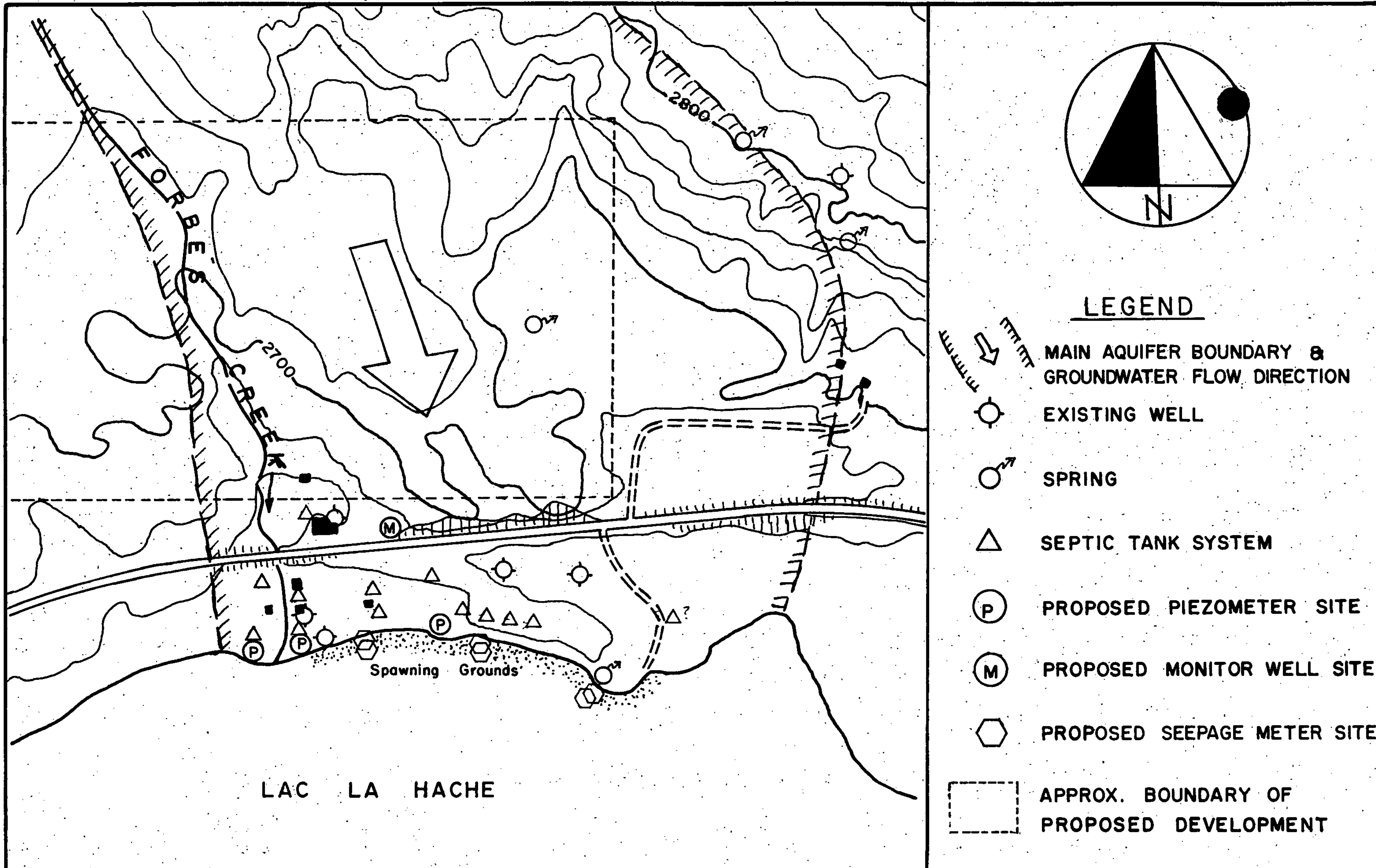
SCALE: VERT. N/A
HOR. 1" = 1320'

DATE NOV. 1982

M.Z. ENGINEER

FILE No. 92 P/13 DWG. No. FIGURE 5

BCIL 7673-M.E.



Province of British Columbia
Ministry of Environment
WATER MANAGEMENT BRANCH

PROPOSED MONITORING SITES
KOKANEE BAY AREA, LAC LA HACHE

SCALE: VERT. .... HOR. 1" = 500'
DATE FEB. '83
MZ ENGINEER
FILE No. 92 P/13 DWG. No. FIGURE 6

VANCAL 8570

TABLE 1

Summary of Well Information

Well No.	Depth (ft.)	Depth to Water (ft.)	Estimated Yield, gpm	Comments
1	26	-	30	Bedrock at 16'
2	105	15	-	Bedrock at 60'
3	66	28	-	Into gravel at bottom
4	60	-	-	From recent survey
5	65	50	-	Till capped
6	60	21	-	Till capped
7	66	28	-	Till capped
8	40	5	-	Bedrock at 30'
9	30	15	-	Bedrock at 25'
10	30	-	-	Only for irrigating lawn
11	45	-	-	From recent survey
12	70	-	-	I.R.#7 well
13	-	-	-	Spring, at lake level
14	-	-	-	Spring
15	-	-	-	Spring
16	140	33	4.5	Bedrock at 47'
17	-	-	-	Spring
18	-	-	-	Spring
19	60	-	-	From recent survey
20	-	-	-	Well capped, not in use
21	-	-	-	Spring
22	-	-	-	From recent survey
23	102	20	-	Bedrock at 80'
24	12	6	-	Dug well
25	94	40	1.5	Bedrock at 34'
26	80	-	8	Bedrock at 65'
27	80	-	3	Bedrock at 40'
28	150	-	-	Reportedly dry
29	84	-	-	Domestic use
30	-	-	-	Spring
31	-	-	-	From recent survey
32	-	-	-	From recent survey
33	32	24	-	6 inch well
34	18	-	-	3' dug well
35	15	-	-	3' x 3' well
36	-	-	-	Dug well, not in use
37	10	4	-	Dug well
38	35	6	5	From recent survey
TH16	26	+26	-	Highways test hole, s & g
TH29	18	12	-	Highways test hole, s & g

TABLE 2

Water Quality Data Summary

Sampling Site	pH	Spec. Cond.	Nitrogen: Ammonia (NH_3 or NH_4)	Nitrite Nitrate	Organic	Total	Phosphorous: Ortho	Total
Well (No.8)	8.1	687	L0.005	0.19	0.12	0.31	0.120	0.126
Well (No.9)	8.0	670	L0.005	0.57	0.15	0.77	0.030	0.030
Well (No.10)	7.4	729	4.340	1.80	1.00	7.00	0.122	0.411
Well (No.11)	7.9	670	L0.005	0.56	0.15	0.71	0.029	0.032
Spring (No.13)	7.7	749	0.009	0.82	0.19	1.02	0.025	0.030
Spring (No.14)	8.3	760	L0.005	L0.02	0.36	0.36	0.003	0.009
Seepage Meter 1	-	-	0.668	L0.02	1.50	2.00	L0.003	0.110
Seepage Meter 3	-	-	L0.007	L0.02	0.71	0.71	L0.003	0.099
Seepage Meter 4	-	-	L0.005	L0.02	0.48	0.48	L0.003	0.048
Seepage Meter 6	-	-	L0.005	L0.02	0.89	0.89	0.016	0.188
Seepage Meter 7	-	-	0.220	L0.02	1.02	1.24	L0.003	0.052

Note:
- Values reported as mg/L except pH, Spec. Cond.
- Locations of Wells and Springs in Figure 2
- Locations of Seepage Meters in Figure 5