NTS File
92 G/1 #49

PROVINCE OF BRITISH COLUMBIA
MINISTRY OF ENVIRONMENT AND PARKS
WATER MANAGEMENT BRANCH

GROUNDWATER SUPPLY CAPABILITY
ABBOTSFORD UPLAND

A.P. Kohut
Groundwater Section
Victoria, British Columbia
May 1987

SYNOPSIS

The Abbotsford Upland encompassing a broad area of 18.6 square miles situated southwest of Abbotsford is underlain by a succession of glacio-fluvial sand and gravel deposits which constitute a major aquifer. In 1985 this aquifer supplied 13.4 cfs on a continuous basis for industrial (41 percent), municipal (34 percent), irrigation (21 percent) and domestic (4 percent) demands. This withdrawal was equivalent to 45 percent of the estimated annual recharge rate of 30 cfs. The total quantity of water pumped in 1985 was estimated at 2.6 billion gallons. Groundwater extraction is presently centered in the southeast corner of the Upland where the Fraser Valley Trout Hatchery and the District of Abbotsford wells account for more than 60 percent of the total Upland withdrawals. Overall groundwater demand since 1982 appears to have been relatively steady but is likely to increase in the future with increased irrigation needs. Future recommended initiatives include enhanced groundwater level monitoring, quantifying in more detail, present and projected irrigation use, regulating extraction in certain areas and further assessing of groundwater use in the Washington State portion of the aquifer.

TABLE OF CONTENTS

	Page
SYNOPSIS	(i)
TABLE OF CONTENTS	(ii)
LIST OF FIGURES	(iii)
LIST OF TABLES	(iv)
LIST OF APPENDICES	(iv)
1. INTRODUCTION	1
2. STUDY AREA	2
3. GENERAL GEOLOGY	2
4. GROUNDWATER OCCURRENCE AND MOVEMENT	4
5. GROUNDWATER LEVEL TRENDS	5
6. GROUNDWATER RECHARGE AND AVAILABILITY	6
7. RECHARGE ESTIMATES	6
8. GROUNDWATER USE	8
Industrial Use	9
Irrigation Use	9
Municipal Use	11
Domestic Use	11
Trends in Use	11
External Factors	12
9. WATER BUDGET	12
10. CONCLUSIONS AND RECOMMENDATIONS	13
11. REFERENCES	16

LIST OF FIGURES

		Page
FIGURE 1	Study area	19
FIGURE 2	Surficial geology	20
FIGURE 3	Well location map	21
FIGURE 4	Geologic cross sections	22
FIGURE 5	Reported water levels	23
FIGURE 6	Water level elevations	24
FIGURE 7	Reported high capacity wells and observation wells	25
FIGURE 8	Hydrographs of observation wells 2, 8, 14 and 15	26
FIGURE 9	Hydrographs of observation wells 272, 273 and 274	27
FIGURE 10	Rates of groundwater withdrawal, Abbotsford Upland, 1985	28
FIGURE 11	Irrigation properties utilizing groundwater	29
FIGURE 12	Water budget Abbotsford Upland, 1985	30

LIST OF TABLES

		Page
TABLE 1	Summary of observation well information, Abbotsford Upland	31
TABLE 2	Summary of recharge estimates, Abbotsford Upland	32
TABLE 3	Estimated groundwater use, Abbotsford Upland, 1985	33

LIST OF APPENDICES

		Page
APPENDIX A	Recharge Calculations	34

GROUNDWATER SUPPLY CAPABILITY, ABBOTSFORD UPLAND

1. INTRODUCTION

In 1985 it was observed that water levels in observation wells located on the Abbotsford Upland (Figure 1) were not responding normally to precipitation since 1982. Based on observed historic water level records for the 1970 to 1981 period and corresponding precipitation, it was anticipated that groundwater levels would follow a rising trend from 1982 to 1984; a period of above normal precipitation. Post 1982 groundwater levels in the observation wells, however, remained relatively static suggesting that groundwater withdrawals from the aquifer may be approaching or exceeding the natural recharge rate.

A study was, therefore, initiated to determine the significance of the post 1982 water level trend being observed and to quantify the average rate of groundwater withdrawal. Information from well records, geologic and groundwater reports and observation well data on file with the Groundwater Section were reviewed. A field inventory was carried out by J. Glass of the Surrey Regional Office during 1985 and 1986 to obtain up-to-date information on existing high capacity wells and groundwater use. Major groundwater users including municipalities, water works districts and the Fraser Valley Trout Hatchery (FVTH) were also visited by P. Sjoman of the Surrey Regional Office to obtain records of 1985 water use.

This report summarizes available information on the aquifers underlying the Abbotsford Upland, reported wells, groundwater movement and rates of aquifer recharge and withdrawal. Comparisons are made between estimated aquifer withdrawals and annual recharge and recommendations for further monitoring procedures are outlined.

2. STUDY AREA

The Abbotsford Upland as shown in Figure 1 encompasses a broad area of 18.6 square miles situated southwest of Abbotsford. The area is bounded on the south by the International Boundary, on the west by Fishtrap Creek and Enns Brook and on the east by the Sumas Prairie Lowland. For purposes of this study the northern boundary has been arbitrarily set along the abandoned railroad line in Sections 19, 20 and 21 in Township 16. The major portion of the Upland lies between elevations of 150 to 250 feet above sea level. The eastern boundary is marked by an escarpment which rises abruptly from the Sumas Prairie Lowland which is at an elevation of 40 feet above sea level.

There are no major streams dissecting the Upland. Fishtrap Creek and small tributaries occur along the western edge of the Upland. A line of springs occurs along the eastern toe of the Upland. These discharge into drainage ditches and Lonzo Creek which flow through the Sumas Prairie Lowland. A number of small lakes namely; Laxton Lake, Abbotsford Lake (Mill Lake) and Judson Lake occur on the upland. The surfaces of these lakes are believed to be an expression of the water table (Halstead, 1959).

The Region is characterized by a cool Mediterranean type of climate in which precipitation falls principally as rainfall during the period September to May. The area receives an average of 1 513 mm of precipitation annually (Environment Canada, 198_). The period from June to September is normally dry and may be subject to drought conditions for short periods.

3. GENERAL GEOLOGY

The Abbotsford Upland is underlain by a succession of unconsolidated glacial and non-glacial deposits of Pleistocene and Recent ages. These deposits are reported to be at least 339 feet in thickness at Clearbrook where they overlie Tertiary bedrock (Armstrong, 1960). During the final stages of deglaciation of the Fraser Lowland a valley glacier occupied the Sumas Valley (Armstrong et al, 1965). During retreat of this Sumas ice an extensive area of glacial fluvial and ice-contact deposits consisting of gravel, sand and lenses of till was laid down in the Abbotsford area. These deposits which mantle most of the Abbotsford Upland were designated by Armstrong (1960) as Abbotsford Outwash. The deposits also extend southwards into the State of Washington (State of Washington, 1960). More recent mapping by Armstrong (1980) delineates these sediments as recessional glaciofluvial deposits within Sumas Drift (Figure 2). Till deposited by Sumas ice underlies the glaciofluvial deposits in many areas and is exposed in north-south trending ridges along the topographically higher regions of the Upland (Figure 2). Older advance glaciofluvial deposits also within the Sumas Drift and comprised of gravel and sand are found along the eastern escarpment of the Upland. These deposits were previously termed Huntingdon Gravel (Armstrong, 1960). Glaciomarine stony silt to loamy clay of the Fort Langley Formation is also found exposed on the Upland northeast of the Abbotsford airport. Eolian deposits comprised of windblown sand and silt up to 8 metres in thickness occur in a north-south trending belt between Mill Lake and the International Boundary. Bog, swamp and shallow-lake deposits comprised of peat occur around Laxton Lake and southwest of the Abbotsford airport.

Subsurface lithologic data from available water wells, the location of which are shown in Figure 3, was utilized to construct representative geologic cross sections through the Abbotsford Upland. Three west to east interpretive cross sections are shown in Figure 4. Locations for these sections are shown in Figure 3. Sand and gravel deposits appear to comprise the major portion of upland deposits to a depth of 150 feet. These are interspersed with discontinuous bodies of till. Due to the lenticular nature of the till it would appear that in many places the younger recessional outwash deposits (Abbotsford Outwash) are in direct contact with older advance outwash deposits (Huntingdon Gravel). This stratigraphic relationship is significant in terms of hydrogeologic continuity, groundwater availability and movement as outlined in the following section.

4. GROUNDWATER OCCURRENCE AND MOVEMENT

The sand and gravel deposits underlying the Abbotsford Upland to a depth of 200 feet below sea level comprise a major hydrostratigraphic unit up to 298 feet in thickness which has been termed the Abbotsford Aquifer (Kohut et al, 1982). Transmissivity values in the range 1.0×10^5 to 1.5×10^5 USgpd/ft. width of aquifer have been reported along the eastern toe of the Upland (Callan, 1971b). The maximum thickness of the Abbotsford Aquifer and the presence of deeper aquifers more than 200 feet below sea level are presently unknown. For the most part groundwater occurs under non-confined or water-table conditions with water levels ranging from 0 to 130 feet below ground. Where glacial till lenses are present, groundwater in underlying sand and gravel deposits can occur under confined conditions. This is evident, for example, in the central portion of cross section A-A[1] (Figure 4) where non-pumping water levels have been reported above the top of the major water-bearing deposits. Non-pumping water levels (feet below ground) based on historic data when the wells were completed or first inventoried are shown in Figure 5. Water levels in the western portion of the Upland are generally shallow (<20 feet below ground). The deepest water levels are found in the central and eastern, topographically higher areas of the Upland. Shallow groundwater levels around Laxton, Judson and Abbotsford lakes indicate that lake levels are closely tied to the water table. Figure 6 depicts the contoured elevations of historic, non-pumping water levels. This map may be used to determine the inferred direction of regional groundwater flow from areas of higher water level elevation (greater hydraulic head) to areas of lower water level elevation (lower hydraulic head). Inferred directions of regional groundwater flow, normal to the water level elevation contours are shown in Figure 6. It is apparent that regional groundwater flow is radially away from the topographically higher north central portion of the Upland towards the outlying western, eastern and northern boundaries. Groundwater flow in the southern portion of the Upland appears to be towards the State of Washington. As the water level information utilized in the preparation of the above maps is based on historic data, and from wells of differing depths, the maps may not be entirely representative of present water level conditions in localized areas.

5. GROUNDWATER LEVEL TRENDS

Seven observation wells are being operated on the Abbotsford Upland, the locations of which are shown in Figure 7. Table 1 summarizes background information on each of the wells. Water level data has been recorded on a continuous basis at four of the sites since 1972. Available hydrograph data for the period 1970 to 1986 are shown in Figures 8 and 9.

During the period 1970 to 1982, water levels in Observation Wells 2 and 8 (Figure 8) located near the central portion of the Upland exhibited a high correlation with cumulative precipitation departure data. However, since 1982 the water levels in these wells have not responded favourably in spite of the above-normal precipitation recorded. The levels have remained relatively steady since 1982 close to previously recorded minimums. Other observation wells which are situated in close proximity to major production wells show similar trends in addition to significant declines due to well interference. A significant lowering of water levels in wells No. 14 and 15, for example, occurred in 1977 as production wells for the Fraser Valley Trout Hatchery became operational.

Over the past twenty-five years a number of wells have been deepened on the Upland to enable landowners to obtain desired quantities of groundwater. During the 1960's, for example, deeper drilled wells were constructed in some areas in existing dug wells to enable extraction of water more efficiently. During the period 1977 to 1979 which was an interval of below normal precipitation, several wells were deepened on the upland.

During field inventory work carried out in 1985 and 1986 several individuals reported their observances of lower groundwater levels in Section 1. TP 13 (South of the Abbotsford Airport) and Sections 3, 4, 8 and 9 of TP 16 (East of the Airport).

6. GROUNDWATER RECHARGE AND AVAILABILITY

Groundwater recharge which includes the entry of water to the saturated zone together with the associated flow away from the water table (Freeze and Cherry, 1979) is difficult to quantify accurately. Estimates of groundwater recharge are, however, important for assessing the rate at which groundwater can be withdrawn on an annual basis (perennial yield) without creating undesirable results, such as, a progressive lowering of water levels in wells and a subsequent reduction in their yields. The term "mining" has been used to designate situations where groundwater withdrawal rates exceed the recharge (Todd, 1980). The recharge rate at any time, however, is dependent upon a number of factors including the effects of groundwater withdrawal which alter the hydrologic regime with time. The perennial yield subsequently varies with time and different patterns of recharge, development and use of groundwater in an area (Todd, 1980). The term "safe yield" commonly used in the past implies a fixed quantity of extractable water from an area and does not take into account factors governing perennial yield, such as, economics, water quality, well locations, well density and legal considerations, for example.

7. RECHARGE ESTIMATES

Halstead (1959) estimated recharge over the entire Abbotsford Upland of 20 square miles at 5×10^9 gals/year (US gallons assumed). This recharge rate would be equivalent to 24 percent of the mean annual precipitation of 1 513 mm. Callan (1971a) estimated recharge over the eastern portion of the upland (6 square miles) to be 10.5 cfs, equivalent to a recharge rate of 41 percent of the mean annual precipitation. This was based in part on measurements of natural discharge of springs along the eastern boundary of the upland.

A number of methods, for example, can be used to estimate groundwater recharge including: water balance, well hydrograph, flow net and infiltration analysis techniques. The water balance method, for example, determines available water surplus for groundwater recharge and surface runoff by calculating the difference between precipitation and potential evapotranspiration (Thornthwaite and Mather, 1957). The hydrograph method involves determining the annual net rise in water level in an observation well accounting for probable discharge during the recharge period and converting this to an equivalent quantity of water necessary to produce the observed water level rise. The unconfined storativity of the aquifer must be approximated to calculate the recharge rate.

Groundwater recharge for the Abbotsford Upland was estimated using two methods; the water balance method of Thornthwaite and Mather (1957) and analyzing available long-term hydrographs for two observation wells (Wells 2 and 8). Results of these estimates are listed in Table 2. Calculations for these estimates are given in Appendix A.

The water balance method (Table 2) indicates recharge to the Abbotsford Upland could be as high as 63 percent of the mean annual precipitation assuming all of the moisture surplus infiltrates to the water table and surface runoff from the Upland does not occur. Due to the coarse textured nature of the surficial deposits and lack of major streams dissecting the Upland it is likely that this high recharge rate is probable. Depending upon which unconfined storativity (specific yield) values are considered, recharge based on the well-hydrograph method varies from 18 to 81 percent of the mean annual precipitation. Assuming a probable specific yield value of 0.25 which is representative of fine to coarse sand and gravel (Johnson, 1967), recharge to the Upland would be in the range 37 to 81 percent which would be comparable to the results of the water balance method. A minimum value of 37 percent would be equivalent to an annual recharge rate of 30 cfs.

The amount of groundwater in storage under the upland can be roughly estimated assuming, for example, that two-thirds of the upland is underlain by aquifer materials having a minimum saturated thickness of 100 feet with an unconfined storativity of 0.25. This quantity would amount to 5.4×10^{10} Igals., the equivalent of 10 years supply at a withdrawal rate of 27 cfs.

8. GROUNDWATER USE

Groundwater on the Abbotsford Upland is used for many purposes including: municipal supplies, irrigation, stock watering, food processing, industrial supplies, fish hatchery requirements and individual residential needs.

In 1980, Zubel estimated groundwater use on the Upland at 16.6 cfs. Water well records on file, the locations of which are shown in Figure 3 indicate the possible existence of some 850 individual wells including 600 drilled wells and 250 shallow dug wells. Many of the shallow dug wells may no longer be in use particularly where municipal supplies have serviced residential communities. The locations of wells having individual capacities >25 gpm are shown in Figure 7.

Irrigation use occurs predominantly in the southern and western portion of the Upland. Municipal wells belonging to the District of Abbotsford, the

District of Matsqui and the Clearbrook Water Works District are centered along the edge of the eastern escapement, within the community of Abbotsford, east of the Abbotsford airport, south of Abbotsford Lake, and within the community of Clearbrook (Figure 7). The Fraser Valley Trout Hatchery wells are situated along the toe of the eastern escarpment.

A summary of the estimated groundwater use in 1985 for the four major use categories namely: industrial, irrigation, municipal and domestic is shown in Figure 10 and listed in Table 3. Total groundwater use in 1985 was estimated to be 2.6×10^9 Igals. or approximately 13.4 cfs. Methods of determining use and information on each of the major users is outlined as follows:

Industrial Use

There are a number of major industrial users of groundwater on the Upland including, for example: the Fraser Valley Trout Hatchery, various food processing firms, the Abbotsford Airport, poultry farms, gravel washing operations, cold storage firms and tree nurseries. The largest single user is the Fraser Valley Trout Hatchery which pumped 9.3×10^8 Igals in 1985; equivalent to 1 770 Igpm on a continuous basis. Groundwater use at the hatchery is metered. The extent of other industrial pumping is not accurately known but could be equivalent to a further 300 Igpm. Halstead (1986), for example, reported 1981 use at Empress Foods in Clearbrook to be 184 026 m^3/year which would be equivalent to 77 Igpm.

Irrigation Use

Total irrigation use is difficult to quantify with any accuracy as most wells are unmetered and demand may vary with time from site to site depending upon several factors including, for example, weather conditions, types of crops grown and methods of irrigation. Information obtained during the 1985 and 1986 irrigation seasons from individual land owners indicates that irrigation wells are generally used for berry crops from June to September (up to 3 months); 10 to 24 hours per day depending upon the weather. In some wet years only a few weeks of irrigation may be required. Irrigation requirements are estimated to be 8 to 12 inches during the irrigation season (pers. comm. T. Van der Gulik, Ministry of Agriculture and Fisheries, December 1986). This would be equivalent to a continuous application rate of 1.6 to 2.1 Igpm per acre during the irrigation season. During the last 10 years irrigators have been shifting to "big gun type" irrigation equipment and subsequently application rates have likely increased to compensate for increased evaporation losses (pers. comm. B. Peters, Ministry of Agriculture and Fisheries, November 1986). Figure 11 shows the inventoried areas of irrigated lands having wells with individual capacities greater than 25 gpm. As all landowners could not be contacted during the 1985-86 survey and some withheld information, these areas represent a minimum area of lands (1,400 acres) irrigated with groundwater. A number of landowners particularly west of Laxton Lake, where the water table is high, pump directly out of dugouts or drainage ditches and not from wells others pump from Laxton and Judson lakes. Raspberry production has apparently increased significantly on the Upland during the last 10 years and has replaced cultivation of strawberries and vegetables for the most part. Of the 6,000 acres of raspberry crops under irrigation in the Fraser Valley, two-thirds to three-quarters (4,000 to 4,500 acres) could be under irrigation on the Upland (pers. comm. B. Peters, Ministry of Agriculture, November 1986). Based on information obtained from landowners in 1985 and 1986 and known existence of high capacity wells it is estimated that about 2,000 acres are presently being irrigated with groundwater.

Based on 2,000 acres of irrigated lands and an application rate of 12 inches over 3 months, the estimated maximum irrigation requirements from groundwater over one season would be 5.4×10^8 Igals, equivalent to an annual withdrawal rate of 1,030 Igpm. As the 1985 irrigation season was especially dry it is possible that irrigation use may have approached these figures. The maximum instantaneous withdrawal rate at the peak of the irrigation season could conceivably be as much as 4,120 Igpm.

Municipal Use

Major municipal users include the District of Abbotsford, the District of Matsqui and the Clearbrook Water Works District. Excellent records provided by these agencies based on metered discharge indicate the total groundwater use in 1985 was 8.9×10^8 Igals. This quantity would be equivalent to a continuous pumping rate of 1,700 Igpm.

Domestic Use

The use of wells for domestic purposes is not large in comparison to other uses as many residents are serviced by municipal systems and individual residential requirements are normally small (<1gpm). If one-half of the 850 existing wells were assumed to be domestic wells in use at 0.5 gpm per residence, the total annual withdrawal would be approximately 220 gpm. It is likely that the true demand is less than this amount.

Trends in Use

Since 1960 groundwater use has increased significantly on the Abbotsford Upland. Lee (1971), for example, estimated annual use in 1970 not including irrigation and domestic requirements at 3,200 gpm. By 1981 this use was approximately double this amount at 5,800 gpm (Halstead, 1986). Estimates for 1985 in this report at 5,020 Igpm indicate that use is still significant. During the last decade municipal use has declined slightly and use at the Fraser Valley Trout Hatchery has been relatively constant. In the early 1980's the District of Matsqui shifted their source of water supply from wells to Norrish Creek with minor augmentation from wells. This reduction in groundwater use was offset to some extent by increased production by the District of Abbotsford for the Sumas Prairie Water System. Irrigation use appears to be increasing with the shift to "big gun type" irrigators which require more water to operate and larger capacity wells to maintain instantaneous flow requirements.

External Factors

As the aquifer underlying the Abbotsford Upland extends southerly into the State of Washington, it is possible that large groundwater withdrawals south of the International Boundary may have some impact upon groundwater conditions north of the border. The present extent of groundwater use south of the border is not known precisely. In 1960 the State of Washington reported that up to 1,725 USgpm was licensed for irrigation of 351 acres along the border in Sections 31 and 33 of T.41 N., R.4E and Sections 34, 35 and 36 in T.41 N., R.3E. The town of Sumas, Washington also utilized springs located in Section 33 T.41N., R.4.E. which were capable of supplying 2,250 USgpm. Average daily use from these springs in 1959 was reported at 120,000 gpd (83 USgpm). A quantity of 1.5 cfs from Judson Lake was also reported to be authorized for irrigation use.

9. WATER BUDGET

A comparison between the estimated aquifer withdrawal in 1985 and the average annual recharge indicates that pumping approached 45 percent of the annual recharge. The water budget for the Abbotsford Upland is depicted schematically in Figure 12. For assumed steady-state conditions in which water table fluctuations are relatively static and there is no significant net change in aquifer storage during the year, the remaining 55 percent of the recharge is lost through natural discharge into springs along the toe of the upland, flow into deeper and contiguous aquifers and evapotranspiration.

A portion of the groundwater withdrawn is also returned to the aquifer as return flow and some is pumped out of the area (eg. to Sumas Prairie).

It would appear, therefore, that groundwater pumping is not presently exceeding the annual recharge on the Upland. In this context, further groundwater development may be warranted in some areas. However, this does not necessarily mean that the present withdrawal rates are not causing some effects such as well interference in localized areas. The major portion of groundwater extraction is presently centered in the southeast corner of the Upland where the Fraser Valley Trout Hatchery and the District of Abbotsford wells presently account for more than 60 percent of the total withdrawals from the Upland. In addition the Town of Sumas pumps from springs close to this same area. Other constraints to further groundwater development including factors such as groundwater quality would also have to be considered. High nitrates for example have been reported in the region south and east of the Abbotsford Airport (Kwong, 1986).

As the overall withdrawal from the Upland does not appear to have increased significantly since 1981 principally due to the decreased use of wells by the District of Matsqui, the lower water levels monitored in observation wells since 1982 probably reflect a localized lowering of levels (well interference) for pumping centered in the southeast corner of the Upland. A detailed level survey would be required to determine the extent and configuration of the major zone of influence of this pumping centre.

10. CONCLUSIONS AND RECOMMENDATIONS

The Abbotsford Upland comprising an area of 18.6 square miles is underlain by a succession of sand and gravel deposits which constitute a major aquifer. This aquifer supplies water for industrial, municipal, irrigation and domestic use. Annual recharge to the Upland is estimated at 30 cfs. Use in 1985 was determined to be 13.4 cfs (5,020 Igpm) on a continuous basis with 41 percent of the demand from industrial consumption, 34 percent from municipal, 21 percent from irrigation and 4 percent from domestic use. Lower water levels monitored in observation wells since 1982 likely reflect a localized lowering of levels due to well interference and are not indicative of a groundwater mining situation in which demand is exceeding the natural recharge. The total quantity pumped in 1985 was estimated at 2.6×10^9 Igals. The major portion of groundwater extraction is presently centered in the southeast corner of the Upland where the Fraser Valley Trout Hatchery and the District of Abbotsford wells account for more than 60 percent of the total Upland withdrawals. Overall demand since 1982 appears to have been relatively steady but is likely to increase in the future with increased irrigation needs. Depending upon the intended use, additional groundwater supplies could be readily developed in some areas of the Upland particularly in the southwest portion where water levels are close to ground surface. Water quality may be a constraint to groundwater development in some areas. Groundwater levels are closely tied to the levels of Laxton, Judson and Abbotsford lakes and groundwater discharge is a major flow component of Fishtrap Creek and springs along the eastern boundary. Well interference caused by major centres of withdrawal and between major production wells locally results in reduced capacities of individual wells. Shallow wells in the topographically higher regions of the Upland are particularly susceptible to these effects and deepening of a number of these wells has been necessary in the past.

As the aquifer underlying the Abbotsford Upland is an important source of water for industrial, municipal and agricultural purposes, continued monitoring of the resource is desirable. The following recommendations are made for consideration:

1. Completing a detailed level survey of water levels within 1 1/2 miles upslope of the Fraser Valley Trout Hatchery and the District of Abbotsford's Farmer Road production wells to determine the configuration

of the major zone of influence of this pumping centre. This would require approximately one man week to establish survey reference points on available wells and 4 man weeks (two weeks for a two-man crew) to complete the level survey. Costs for this work including salaries and expenses are estimated at $5,000.00.

2. Establishing two additional observation wells; one located southwest of the Abbotsford Airport close to an area of high irrigation demand and a second well along Huntingdon Road between existing Observation Wells 2 and 8. It may be possible to obtain an abandoned domestic well for this purpose. Contract costs for constructing and equipping one 6-inch diameter observation well are estimated at $9,000 excluding engineering supervisory costs.

3. Undertaking additional investigations of present and projected irrigation use of groundwater on the upland to refine quantitative estimates. A study of this type would best be undertaken in cooperation with the Ministry of Agriculture and may be appropriate for a consulting firm. Costs for this work could range from $10,000 to $30,000 depending upon the scope of the investigations.

4. In areas such as the southeastern portion of the Abbotsford Upland where there is intensive groundwater use and substantial investments have been committed, consideration should be given to regulating any additional groundwater extraction in excess of individual domestic requirements through licensing or appropriate land-use zoning to safeguard the source of water supply for existing developments.

5. Liaising with Washington State officials to ascertain the significance of groundwater use in the Washington State portion of the aquifer. Visits to appropriate State offices and the Town of Sumas Waterworks are recommended. One man-week of engineering time and approximately $300 for travel costs would be required for this work.

11. REFERENCES

Armstrong, J.E. 1960. Surficial Geology of Sumas Map - Area, British Columbia, 92 G/1. Geological Survey of Canada, Paper 59-9.

Armstrong, J.E. 1980. Surficial Geology, Mission, British Columbia. Geological Survey of Canada, Map 1485A.

Callan, D.M. 1971a. Recommendations For Development of a Groundwater Aquifer at the Fraser Valley Trout Hatchery Near Abbotsford, B.C. Ministry of Environment, Groundwater Section File 92 G/1.

Callan, D.M. 1971b. Results of an Eight-day Field Pumping Test of Two Production Wells at the Fraser Valley Trout Hatchery Near Abbotsford, September 1970, Ministry of Environment, Groundwater Section, File: 92 G/1.

Environment Canada. 198 ___. Canadian Climate Normals, 1951-1980, British Columbia. Atmospheric Environment Service.

Freeze, R.A. and J.A. Cherry. 1979. Groundwater. Prentice-Hall Inc. New Jersey.

Halstead, E.C. 1959. Ground-Water Resources of Matsqui Municipality British Columbia. Geological Survey of Canada, Water Supply Paper No. 328.

Halstead, E.C. 1986. Ground Water Supply - Fraser Lowland, British Columbia. Inland Waters Directorate, Scientific Series No. 145, NHRI Paper No. 26.

Johnson, A.I. 1967. Specific yield - compilation of specific yields for various materials. U.S. Geological Survey, Water Supply Paper 1662-D, 74pp.

Kohut, A.P., M. Zubel and H.H. Choy. 1982. Utilization of cumulative precipitation departure trends in assessing long-term water level fluctuations in shallow aquifers in British Columbia. Proceedings, second National Hydrogeological Conference, International Association of Hydrogeologists, Canadian National Chapter, pp. 137-147.

Kwong, J.C. 1986. Groundwater Quality Monitoring and Assessment Program. The Occurrence of Nitrate-Nitrogen in Groundwater in the Langley-Abbotsford Area. B.C. Ministry of Environment, Water Management Branch, Memorandum Report, File 0329563-A.

Lee, E. 1971. Regional Water Supply Study, Planning Department, Central Fraser Valley Regional District.

State of Washington. 1960. Water Resources of the Nooksack River Basin and Certain Adjacent Streams. Department of Conservation, Division of Water Resources, Olympia, Washington, 187 pp.

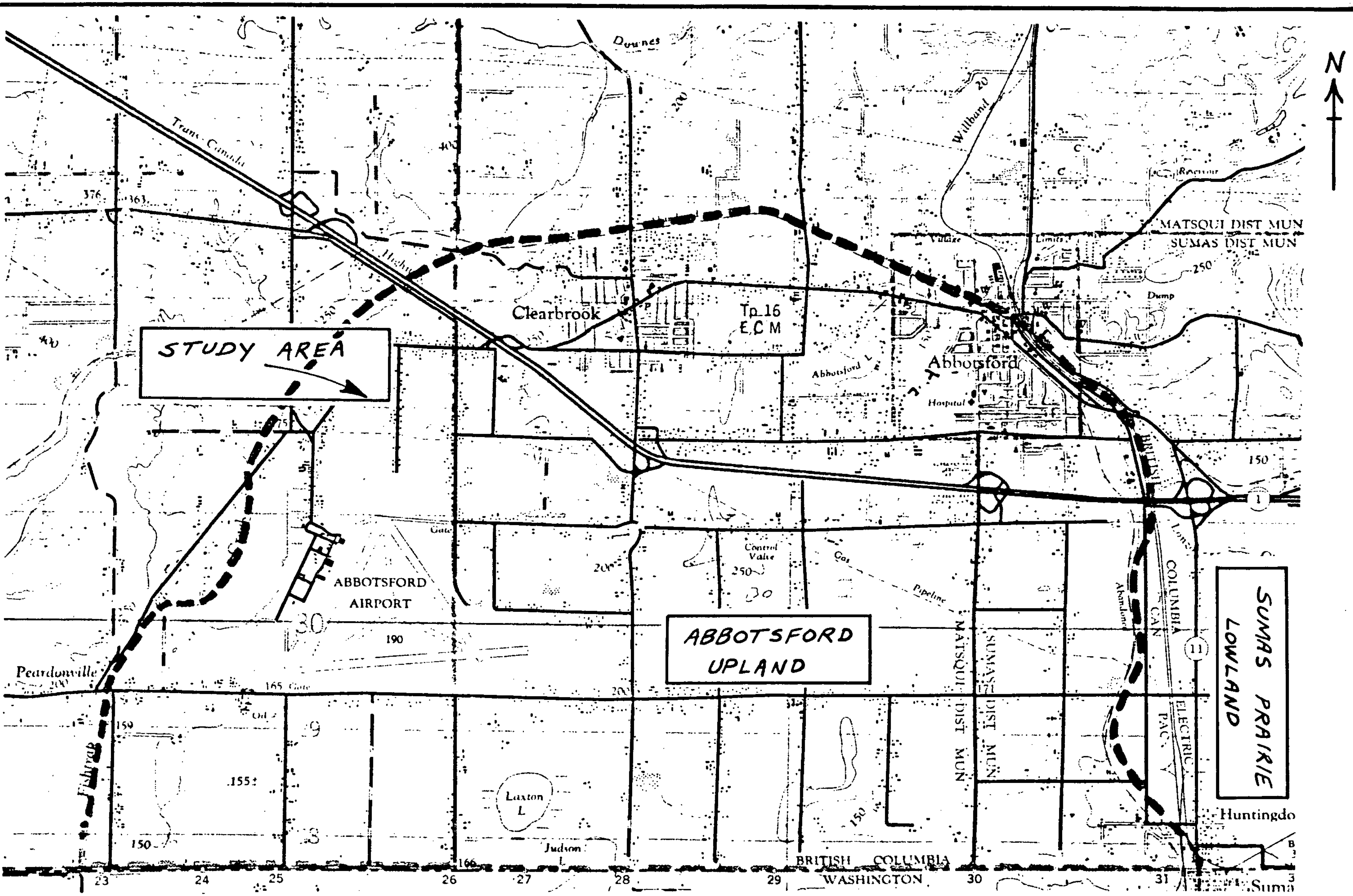
Thornthwaite, C.W. and Mather, J.R. 1957. Instructions and tables for computing potential evapotranspiration and the water balance. Publications in Climatology. Vol. 10, No. 3. Drexel Institute of Technology, Laboratory of Climatology, Centerton, New Jersey.

Todd, D.K. 1980. Groundwater Hydrology, Second Edition. John Wiley and Sons, New York.

Zubel, M. 1979. Fraser Valley Trout Hatchery, Production well performance and data analysis, Water Management Branch, Groundwater Section 92 G/1, B.C. Ministry of Environment.

Zubel, M. 1980. Sumas Prairie Water Supply - Farmer Road Well No. 2, Water Management Branch, Groundwater Section, File 92 G/1, B.C. Ministry of Environment.

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

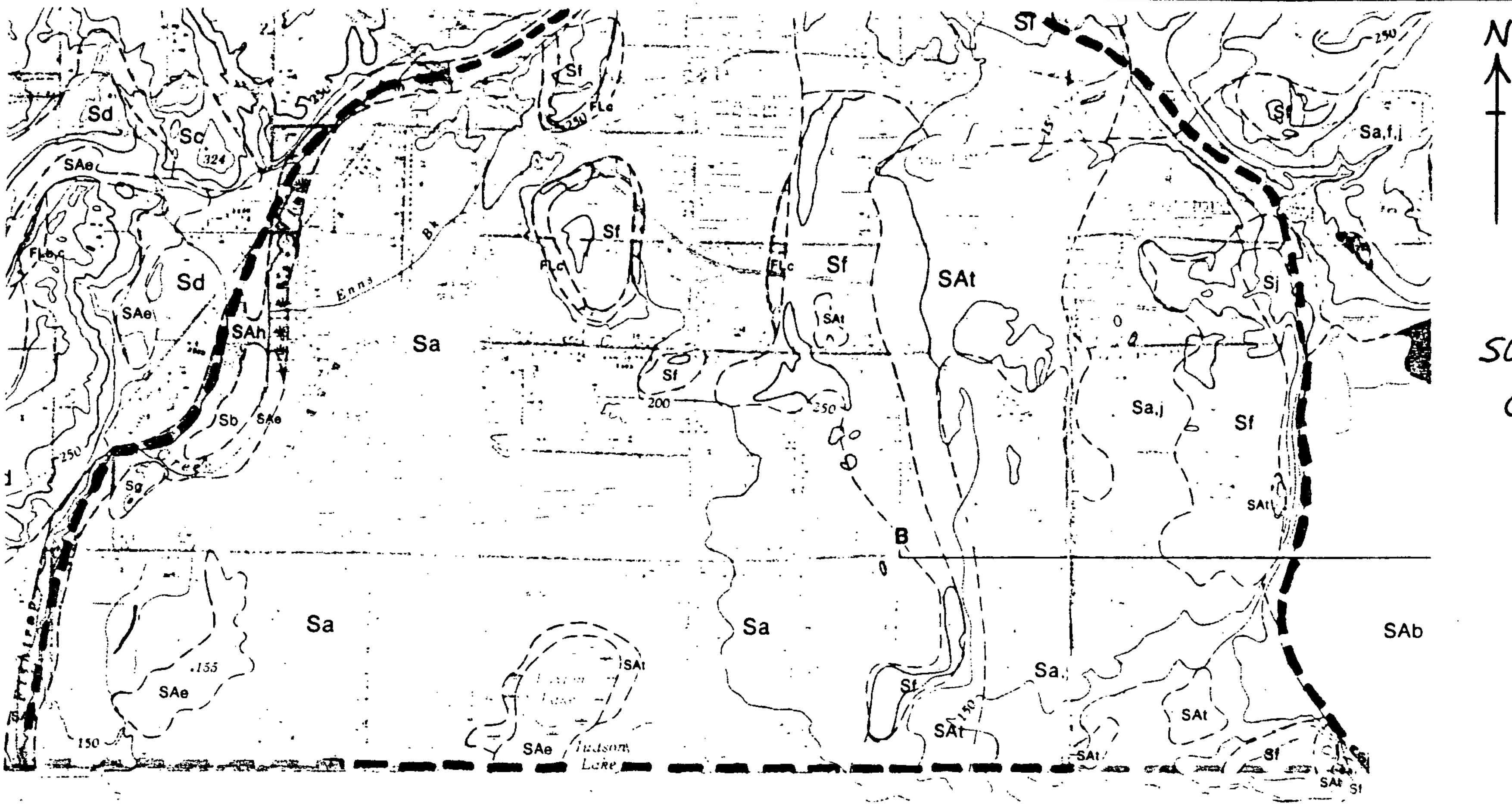


Province of British Columbia
Ministry of Environment
WATER MANAGEMENT BRANCH

TO ACCOMPANY REPORT ON

GROUNDWATER SUPPLY CAPABILITY ABBOTSFORD UPLAND

SCALE: VERT. — HOR. 1:50,000	DATE NOV. 1986
APK ENGINEER	
FILE No.	DWG. No. FIGURE 1



SURFICIAL GEOLOGY

LEGEND

SAb-e	*Bog, swamp, and shallow lake deposits:*
SAt	*Eolian deposits*
Sa,e,i	*Recessional glaciofluvial deposits:*
Sj	*Advance glaciofluvial deposits*
Sf,g	*Lodgment and minor flow till:*
FLa,c,d	*Glaciomarine deposits*

from ARMSTRONG (1980).

Province of British Columbia
Ministry of Environment
WATER MANAGEMENT BRANCH

TO ACCOMPANY REPORT ON
GROUNDWATER SUPPLY CAPABILITY
ABBOTSFORD UPLAND

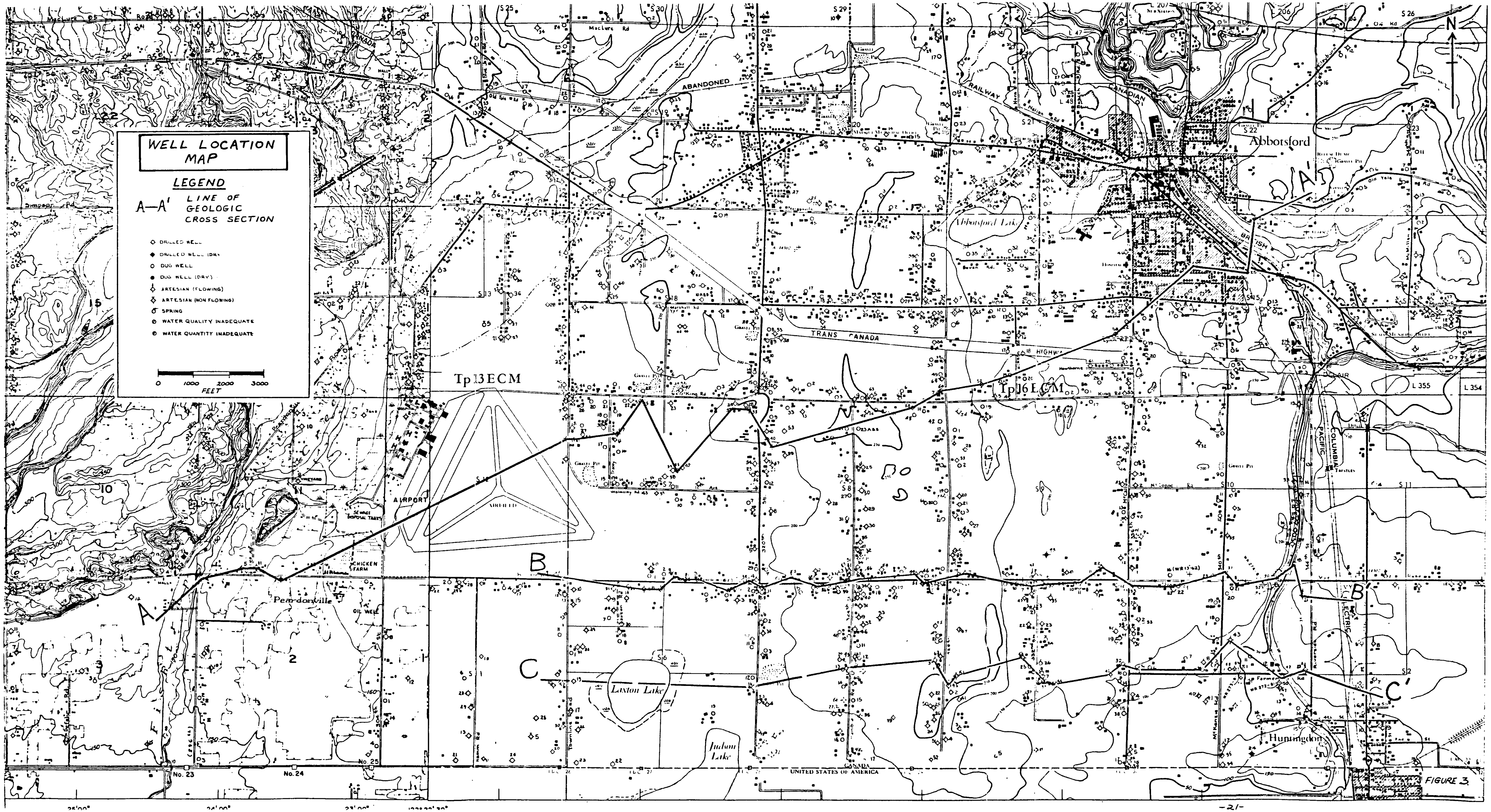
SCALE: VERT.
HOR. 1:50,000

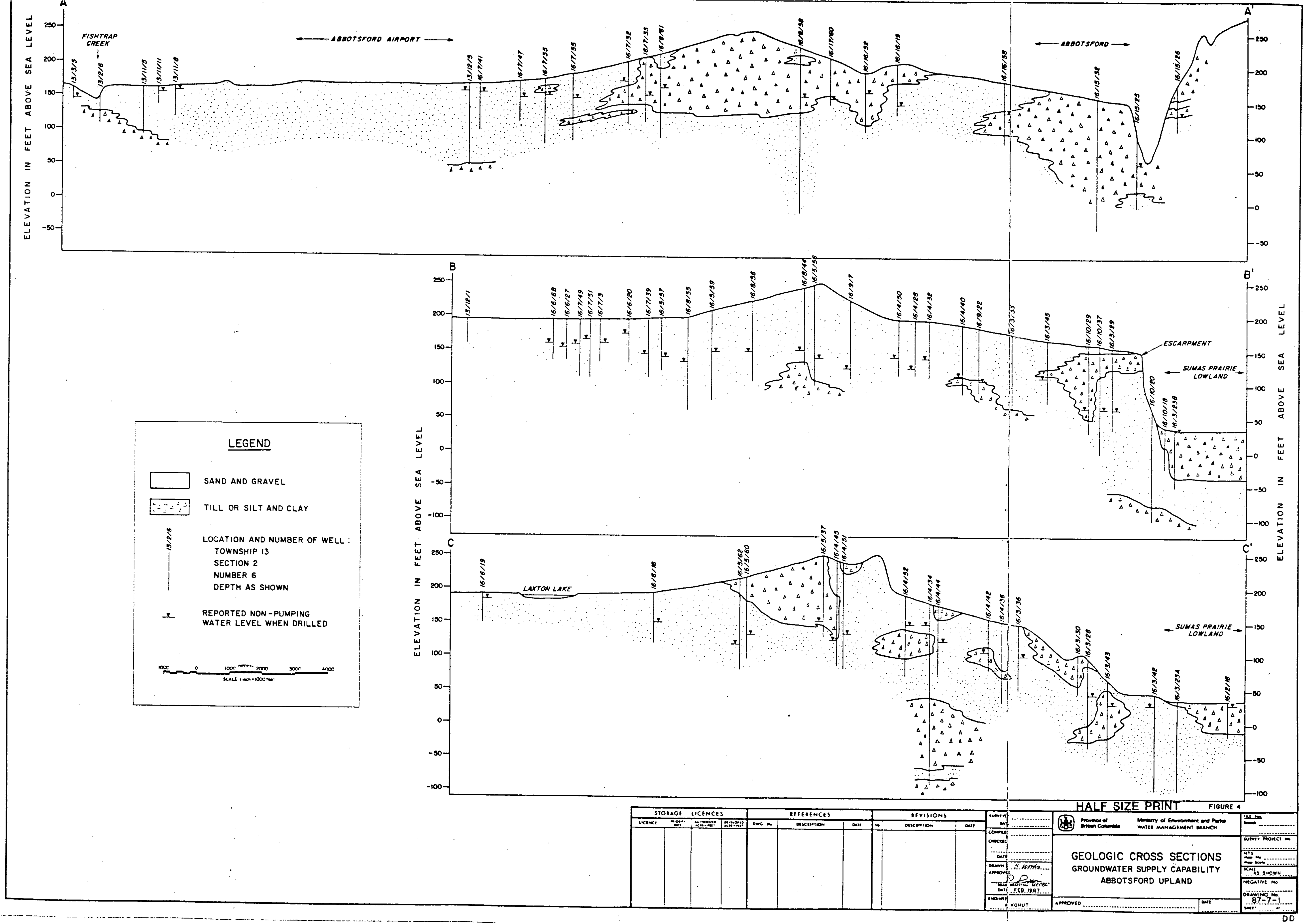
DATE NOV. 1986.

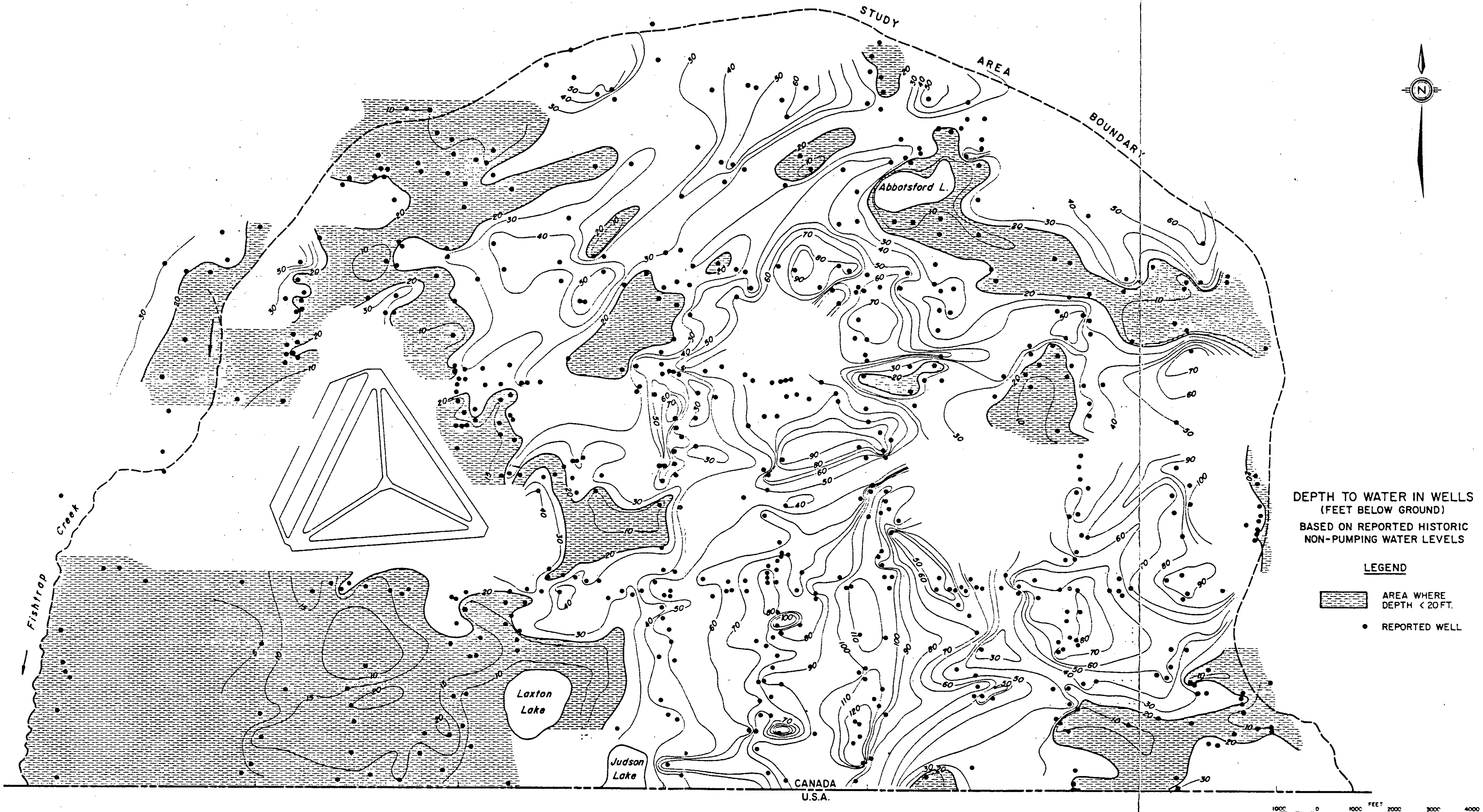
APK ENGINEER

FILE No. DWG. No. FIGURE 2

BCIL 7674-ME


WELL LOCATION MAP
LEGEND
A—A' LINE OF GEOLOGIC CROSS SECTION
DRILLED WELL
DRILLED WELL (DRY)
DUG WELL
DUG WELL (DRY)
ARTESIAN (FLOWING)
ARTESIAN (NON FLOWING)
SPRING
WATER QUALITY INADEQUATE
WATER QUANTITY INADEQUATE
0 1000 2000 3000
FEET
N
Abbotsford
Abbotsford Lake
Tp 13 ECM
Tp 16 ECM
TRANS CANADA HIGHWAY
ABANDONED RAILWAY
CANADIAN
BRITISH COLUMBIA ELECTRIC
PACIFIC
AIRPORT
AIRFIELD
CHICKEN FARM
Peardonville
OIL WELL
Laxton Lake
Judson Lake
Huntingdon
UNITED STATES OF AMERICA
CANADA
A
A'
B
B'
C
C'
No. 23
No. 24
No. 25
King Rd
Marshall Rd
MacLure Rd
Simpson Rd
L 355
L 354
FIGURE 3


A
A'
FISHTRAP CREEK
ABBOTSFORD AIRPORT
ABBOTSFORD
ELEVATION IN FEET ABOVE SEA LEVEL
B
B'
ESCARPMENT
SUMAS PRAIRIE LOWLAND
C
C'
LAXTON LAKE
SUMAS PRAIRIE LOWLAND
LEGEND
SAND AND GRAVEL
TILL OR SILT AND CLAY
LOCATION AND NUMBER OF WELL :
TOWNSHIP 13
SECTION 2
NUMBER 6
DEPTH AS SHOWN
REPORTED NON-PUMPING WATER LEVEL WHEN DRILLED
SCALE 1 inch = 1000 feet
HALF SIZE PRINT
FIGURE 4
STORAGE LICENCES
REFERENCES
REVISIONS
Province of British Columbia
Ministry of Environment and Parks
WATER MANAGEMENT BRANCH
GEOLOGIC CROSS SECTIONS
GROUNDWATER SUPPLY CAPABILITY
ABBOTSFORD UPLAND
FEB. 1987
KOHUT
AS SHOWN
87-7-1
DD



HALF SIZE PRINT

FIGURE 5

STORAGE LICENCES				REFERENCES			REVISIONS		
LICENCE	PRIORITY DATE	AUTHORIZED ACRE-FEET	DEVELOPED ACRE-FEET	DWG No	DESCRIPTION	DATE	No	DESCRIPTION	DATE

Province of British Columbia — Ministry of Environment and Parks, WATER MANAGEMENT BRANCH

REPORTED WATER LEVELS

GROUNDWATER SUPPLY CAPABILITY

ABBOTSFORD UPLAND

SURVEYED .... DATE ....

COMPILED ....

CHECKED .... DATE ....

DRAWN E. Kirvda [signature]

APPROVED [signature] HEAD DRAFTING SECTION

DATE FEB. 1987

ENGINEER A. KOHUT

APPROVED .... DATE ....

FILE No .... Branch ....

SURVEY PROJECT No ....

NTS Map No .... Map Scale ....

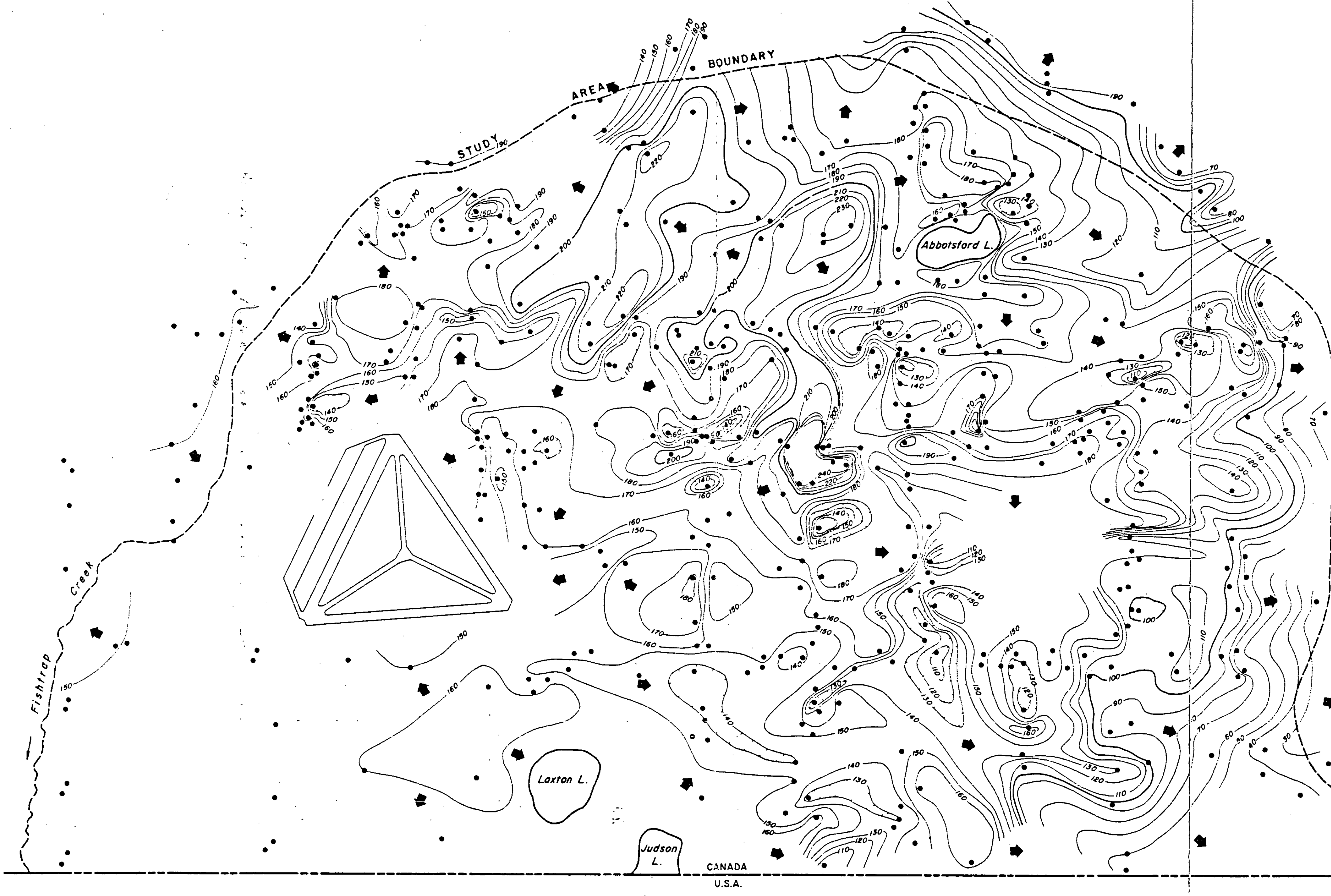
SCALE AS SHOWN

NEGATIVE No ....

DRAWING No 87-7-2

SHEET ... of ...

DD



ELEVATION OF WATER LEVEL IN WELLS

(FEET ABOVE SEA LEVEL)

BASED ON REPORTED HISTORIC NON-PUMPING WATER LEVELS

LEGEND

- • REPORTED WELL
- INFERRED DIRECTION OF GROUNDWATER FLOW
- —100— WATER LEVEL CONTOUR CONTOUR INTERVAL = 10 FEET

HALF SIZE PRINT

FIGURE 6

STORAGE LICENCES	REFERENCES	REVISIONS

Province of British Columbia — Ministry of Environment and Parks — WATER MANAGEMENT BRANCH

WATER LEVEL ELEVATIONS

GROUNDWATER SUPPLY CAPABILITY

ABBOTSFORD UPLAND

DATE FEB 1987

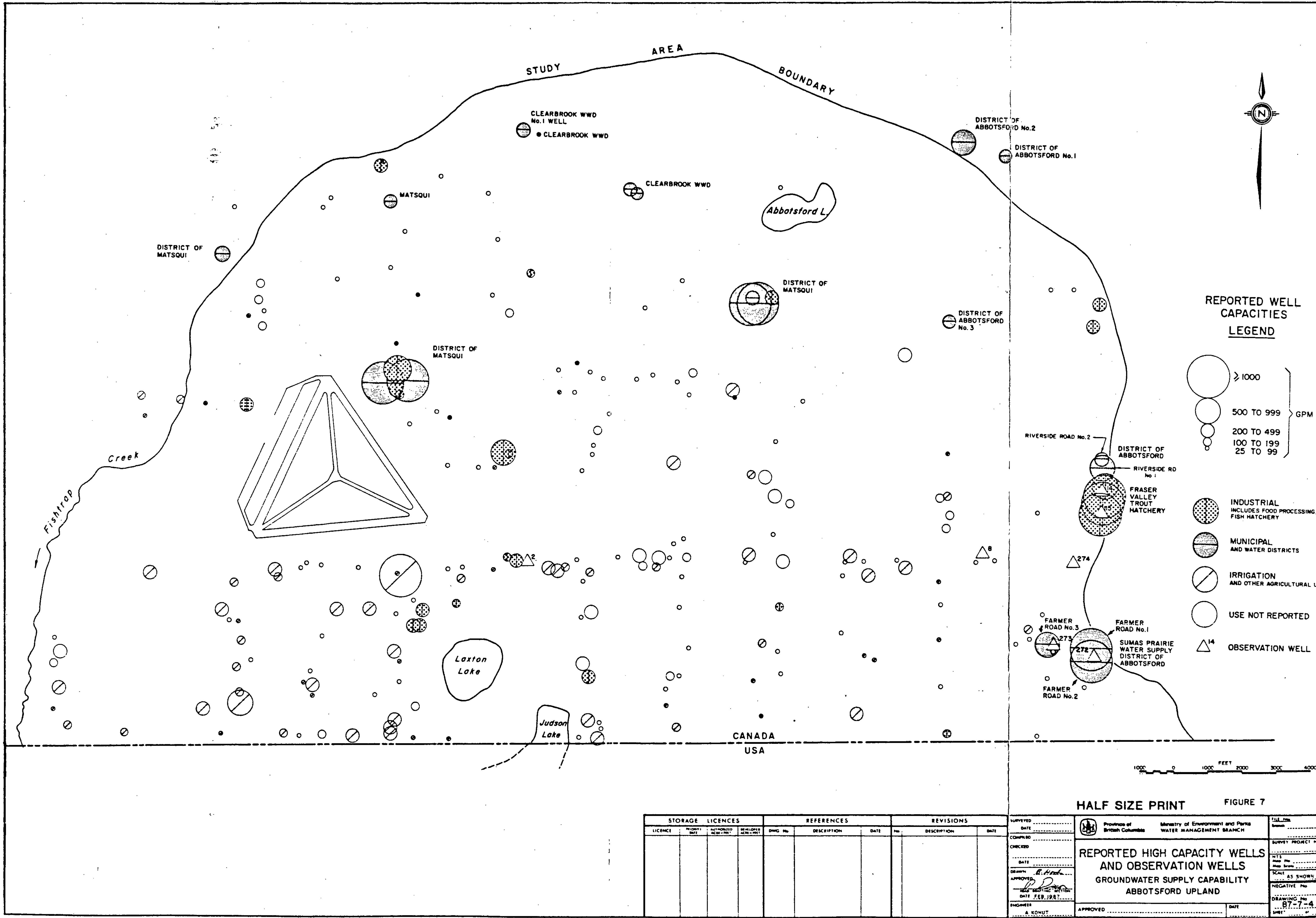
ENGINEER A. KOHUT

SCALE AS SHOWN

DRAWING No. 87-7-3

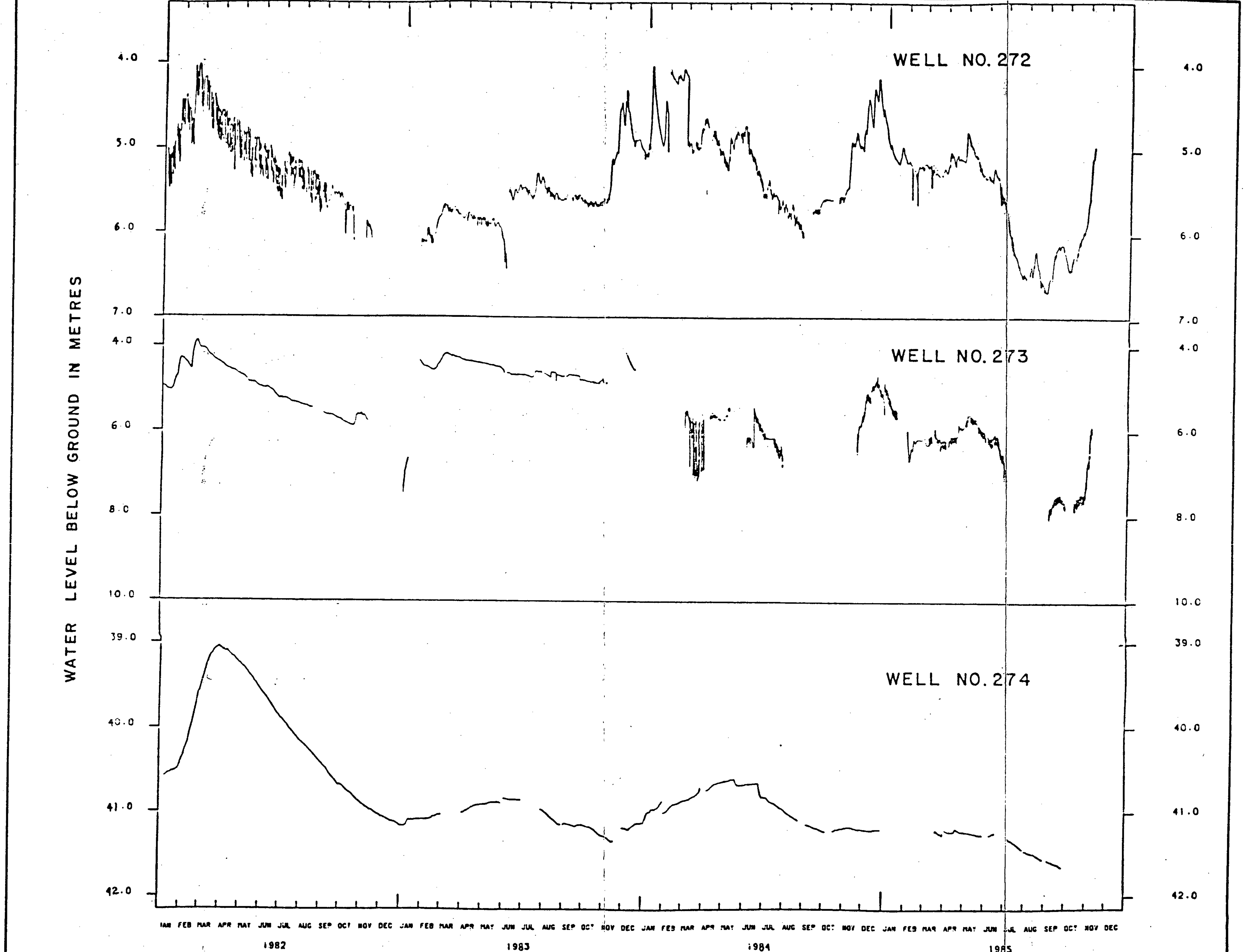
APPROVED

DD


STUDY AREA BOUNDARY
CLEARBROOK WWD No.1 WELL
CLEARBROOK WWD
CLEARBROOK WWD
MATSQUI
DISTRICT OF MATSQUI
DISTRICT OF MATSQUI
DISTRICT OF MATSQUI
Abbotsford L.
DISTRICT OF ABBOTSFORD No.2
DISTRICT OF ABBOTSFORD No.1
DISTRICT OF ABBOTSFORD No.3
Fishtrap Creek
Laxton Lake
Judson Lake
CANADA
USA
RIVERSIDE ROAD No.2
DISTRICT OF ABBOTSFORD
RIVERSIDE RD No.1
FRASER VALLEY TROUT HATCHERY
FARMER ROAD No.3
FARMER ROAD No.1
SUMAS PRAIRIE WATER SUPPLY DISTRICT OF ABBOTSFORD
FARMER ROAD No.2
274
273
272
REPORTED WELL CAPACITIES
LEGEND
≥ 1000
500 TO 999
200 TO 499
100 TO 199
25 TO 99
GPM
INDUSTRIAL
INCLUDES FOOD PROCESSING, FISH HATCHERY
MUNICIPAL
AND WATER DISTRICTS
IRRIGATION
AND OTHER AGRICULTURAL USE
USE NOT REPORTED
OBSERVATION WELL
FEET
1000 0 1000 2000 3000 4000
STORAGE LICENCES
REFERENCES
REVISIONS
HALF SIZE PRINT
FIGURE 7
Province of British Columbia
Ministry of Environment and Parks
WATER MANAGEMENT BRANCH
REPORTED HIGH CAPACITY WELLS AND OBSERVATION WELLS
GROUNDWATER SUPPLY CAPABILITY
ABBOTSFORD UPLAND
DATE FEB. 1987
ENGINEER A. KONUT
SCALE AS SHOWN
DRAWING No 87-7-4
DD

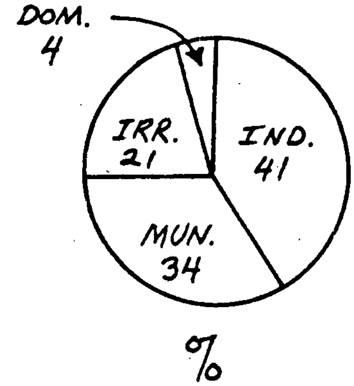
OBSERVATION WELL HYDROGRAPHS

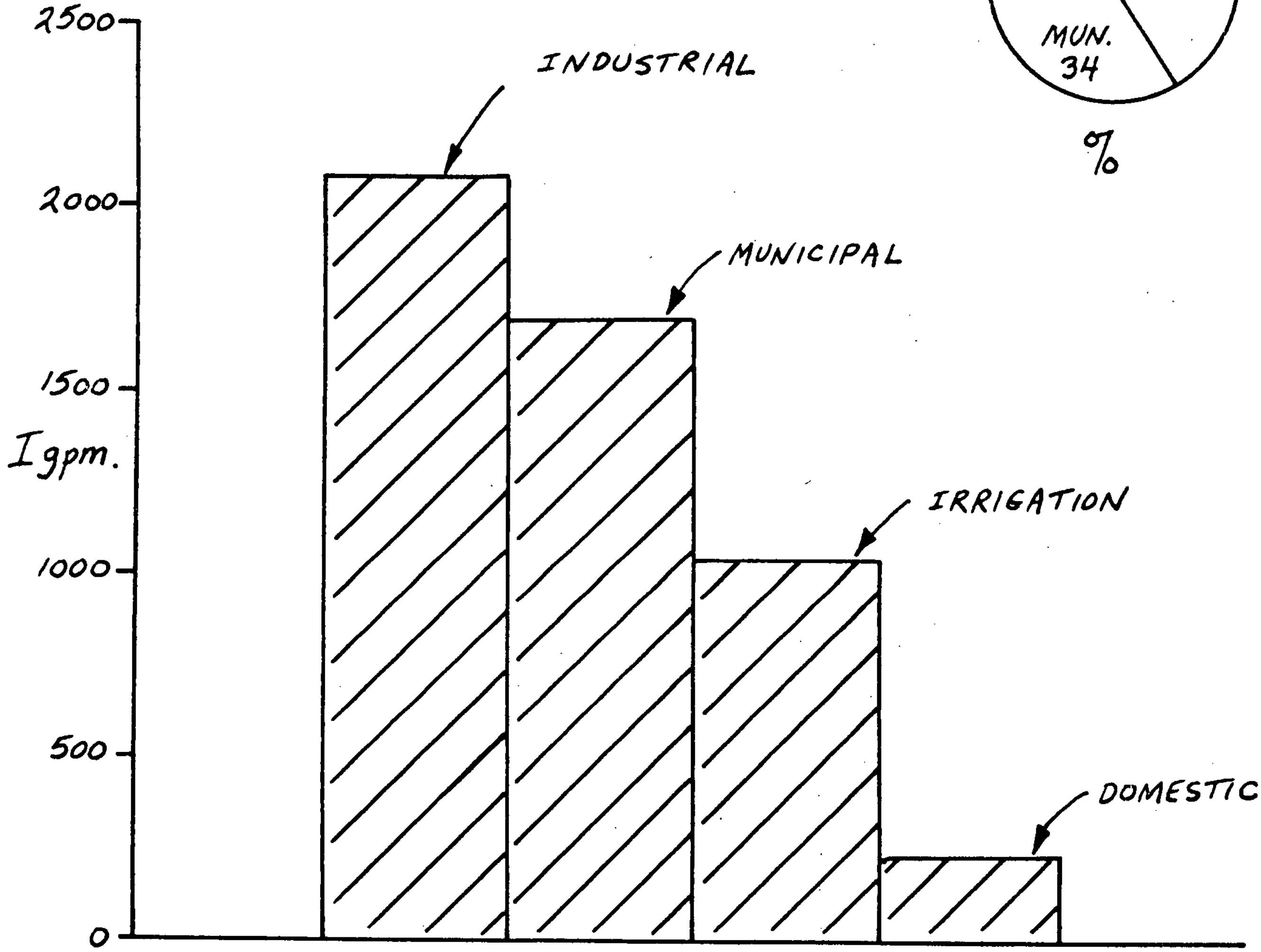
FIGURE 8.



OBSERVATION WELL HYDROGRAPHS

FIGURE 9.



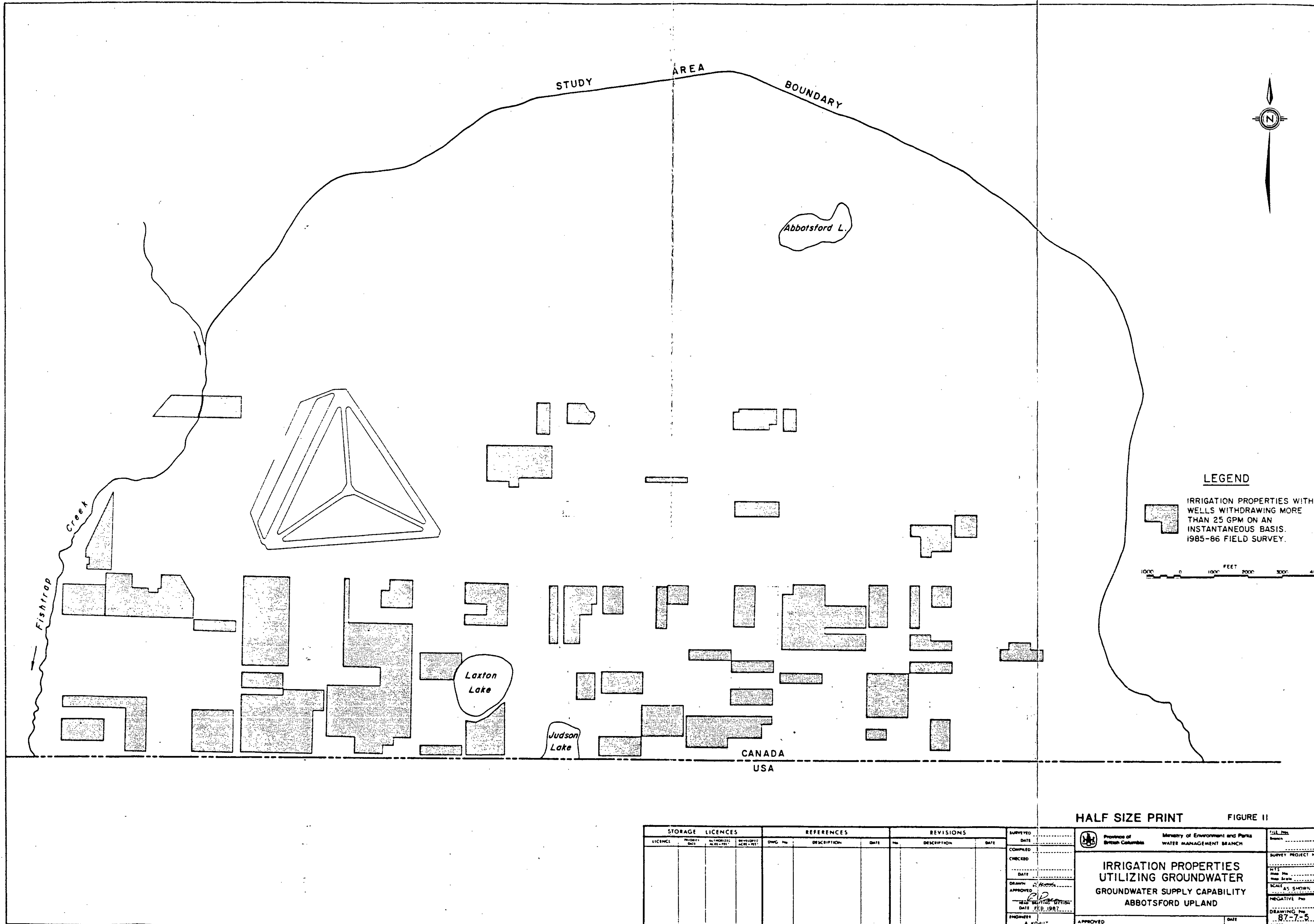


RATES OF GROUNDWATER WITHDRAWAL ABBOTSFORD UPLAND, 1985.

TOTAL = 5020 Igpm
= 13.4 CFS.

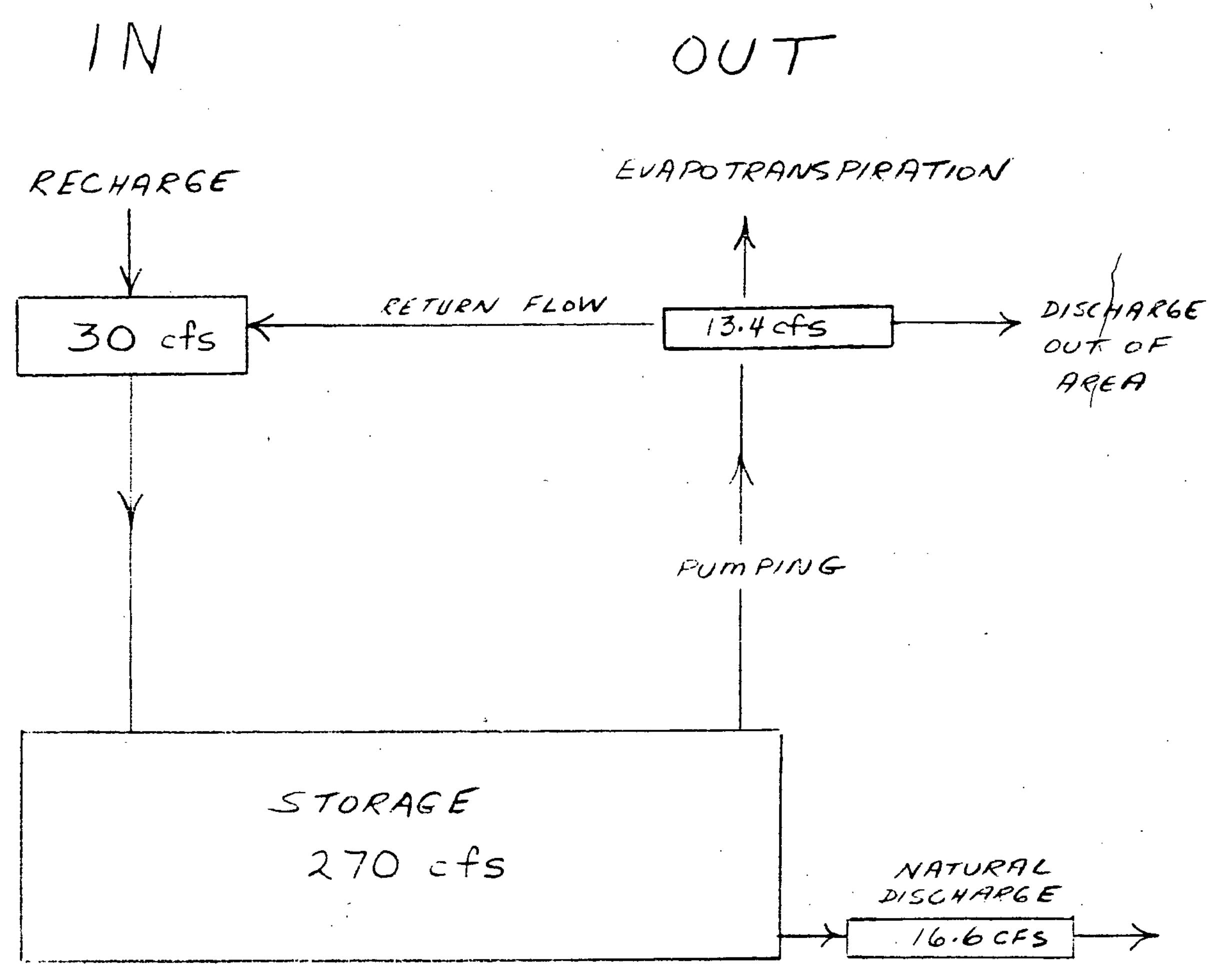
Province of British Columbia Ministry of Environment WATER MANAGEMENT BRANCH	TO ACCOMPANY REPORT ON GROUNDWATER SUPPLY CAPABILITY ABBOTSFORD UPLAND
SCALE VERT — HOR —	DATE NOV. 1986.
APK ENGINEER	FILE No ... DWG No. FIGURE 10.

VAN CAL 15712



HALF SIZE PRINT

FIGURE 11



WATER BUDGET ABBOTSFORD UPLAND, 1985

Province of British Columbia Ministry of the Environment ENVIRONMENTAL AND ENGINEERING SERVICE WATER INVESTIGATIONS BRANCH	TO ACCOMPANY REPORT ON GROUNDWATER SUPPLY CAPABILITY ABBOTSFORD UPLAND	SCALE: VERT. — HOR. —	DATE DEC 1986
		APK ENGINEER	
		FILE No.	DWG. No. FIGURE 12.

bril 6661 wrs

TABLE 1

SUMMARY OF OBSERVATION WELL INFORMATION, ABBOTSFORD UPLAND

Well No.	Reference Location	Date Completed	Depth Ft.	Diameter Inches	Non-Pumping Water Level When Completed	Screen Location Feet	Screen Size	Lithology
2	TWP16SEC7#3	1972	63	6	33'4"(1972)	58-63	20 slot	sd. + gr.
8	TWP16SEC10#16	1972	86	6	55.21' (1972)	82-86	40 slot	sd. + gr. locally silty 0-87
14	TWP16SEC10#24	1971	155	6	21' (1971)	150-155	40 slot	sd. + gr. 0-171 171-251 clay
15	TWP16SEC10#26	1971	320?	8	20' (1971)	?	?	sd. + gr. with silty zones
272	TWP16SEC3#50	1981	119	6	20' (Oct 1981)	111-119	20 slot 6" T.S.	sd. + gr. 0-119
273	TWP16SEC3#51	1981	108	6	18' (Oct 1981)	100-108	20 slot 6" T.S.	sd. + gr. 0-108 till 108-112
274	TWP16SEC3#52	1981	218	6	134' (Oct 1981)	210-218	20 slot 6" T.S.	sd. + gr. 0-220

TABLE 2

SUMMARY OF RECHARGE ESTIMATES, ABBOTSFORD UPLAND

Method	Period of Record	Water Holding Capacity of Soil in Unsaturated Zone (Soil Type)	Unconfined Storativity In Saturated Zone	Recharge as Percentage of Mean Annual Precipitation	Annual Recharge Rate for Entire Upland Area (CFS)
A. Water Balance	1951-1980	100 mm/m fine sand	--	63	51
B. Hydrograph Analysis	1973-1984	--	0.3	53	43
(Well No. 8)	1973-1984	--	0.2	37	30
	1973-1984	--	0.10	18	15
(Well No. 2)	1975-1984	--	0.3	81	66
	1975-1984	--	0.2	54	44
	1975-1984	--	0.1	27	22

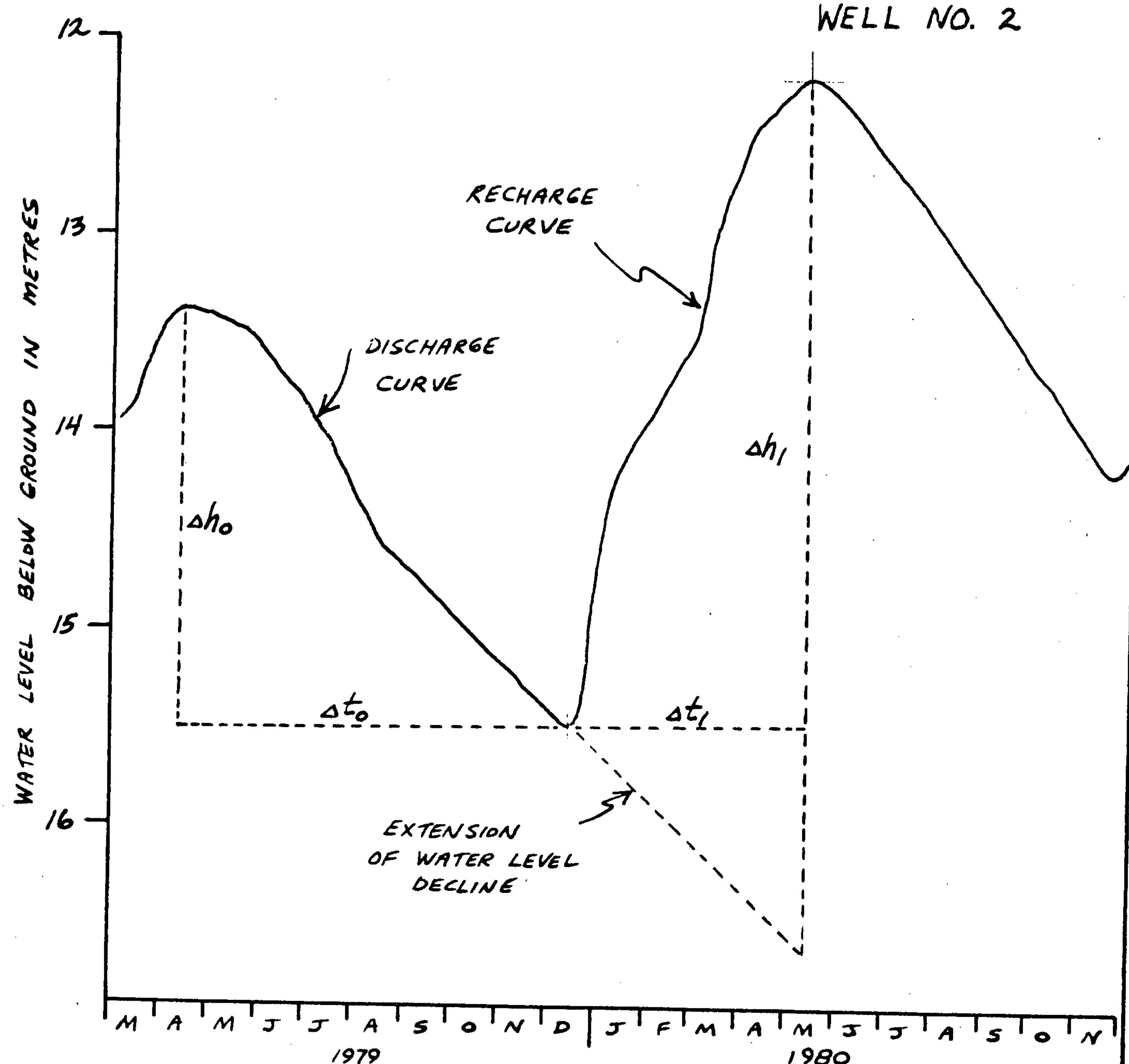
TABLE 3

ESTIMATED GROUNDWATER USE, ABBOTSFORD UPLAND 1985

User	Well	Output (Igals)		
District of Abbotsford	Farmer Road No. 1	234,119,000		
	Farmer Road No. 2	1,811,976		
	Farmer Road No. 3	179,211,243		
	Well No. 2	13,022,000		
	Riverside No. 1	210,052,000		
			638,216,219	
District of Matsqui	Townline No. 1	22,916,014		
	Townline No. 2	18,160,648		
			41,076,662	
Clearbrook Water Works	4 Wells	211,632,400		
			211,632,400	
				890,925,281
Fraser Valley Trout Hatchery	4 Wells	930,312,000		
			930,312,000	930,312,000
Other Industries		157,680,000		
			157,680,000	157,680,000
Irrigation	---	541,368,000		
			541,368,000	541,368,000
Domestic	---	115,632,000		
			115,632,000	115,632,000
			Total:	2,635,917,281

APPENDIX A

HYDROGRAPH METHOD FOR ESTIMATING RECHARGE



$$\text{RECHARGE RATE } (R) = \frac{\Delta h_1 n}{\Delta t_1} + \left(\frac{\Delta h_0 n \, \Delta t_1}{\Delta t_0}\right)\left(\frac{1}{\Delta t_1}\right)$$

$$R = n\left(\frac{\Delta h_1}{\Delta t_1} + \frac{\Delta h_0}{\Delta t_0}\right) \text{ m/month}$$

WHERE Δh_0 = WATER LEVEL DECLINE (m)

Δh_1 = WATER LEVEL RISE (m)

Δt_0 = PERIOD OF WATER LEVEL DECLINE (m)

Δt_1 = PERIOD OF WATER LEVEL RISE (m)

n = UNCONFINED STORATIVITY (DIMENSIONLESS)

Province of British Columbia Ministry of Environment WATER MANAGEMENT BRANCH	TO ACCOMPANY REPORT ON GROUNDWATER SUPPLY CAPABILITY ABBOTSFORD UPLAND
SCALE: VERT AS SHOWN HOR AS SHOWN — DATE NOV 1986.	APK ENGINEER FILE No. APPENDIX A DWG No. FIGURE 1.

APPENDIX A
TABLE 1
WATER BALANCE
USING METHOD OF THORNTWAITE AND MATHER (1957)

Station: Abbotsford A   Period of Record 1951-1980

Lat. + Long: 49°2'N 122°22'W 59m

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOT
TEMPERATURE,(°C) (MEAN MONTHLY)	1.6	4.4	5.6	8.7	12.0	14.7	17.0	16.9	14.5	10.1	5.6	3.2	--
HEAT INDEX, I	0.18	0.82	1.19	2.31	3.76	5.12	6.38	6.32	5.01	2.90	1.19	0.51	35.69
UNADJUSTED PE	0.2	0.7	0.9	1.4	1.9	2.4	2.8	2.8	2.4	1.6	0.9	0.5	18.5
LATITUDE CORRECTION	22.5	23.7	30.6	34.5	39.6	40.2	40.5	37.2	31.5	27.6	22.8	21.3	--
ADJUSTED PE	4.5	16.59	27.54	48.3	75.24	96.48	113.4	104.16	75.6	44.16	20.52	10.65	637.14
PRECIPITATION P (MEAN MONTHLY)	209.4	159.5	139.3	102.4	78.2	64.5	41.2	55.9	89.6	153.4	191.8	227.8	1513.0
P - PE	204.9	142.91	111.76	54.1	2.96	-31.98	-72.2	-48.26	14	109.24	171.28	217.15	911.82
ACCUM. POTENTIAL WATER LOSS						-31.98	-104.18	-152.44					
STORAGE	100	100	100	100	100	72	34	- 21	35	100	100	100	
STORAGE	0	0	0	0	0	-28	-38	- 13	14	65	0	0	
AE	4.5	16.59	27.54	48.3	75.24	92.5	79.2	68.9	75.6	44.16	20.52	10.65	563.7
MOISTURE SURPLUS	204.9	142.91	111.76	54.1	2.96	0	0	0	0	44.24	171.28	217.15	949.3

WATER HOLDING CAPACITY OF SOIL 100 mm/m.   SOIL TYPE Fine Sand

RECHARGE AS PERCENTAGE OF MEAN ANNUAL PRECIPITATION $= \frac{949.3}{1513.0} \times 100 = 63\%$

APPENDIX A

TABLE 2

SUMMARY OF DATA FOR RECHARGE CALCULATIONS, OBSERVATION WELL 2

RECHARGE PERIOD	ho metres)	to (months)	h_1 (metres)	t_1 (months)	n	R (m/month) x 10^{-2}
1974-75	3.469	7.82	2.25	3.59	0.1	10.71
					0.2	21.42
					0.3	32.13
1975-76	2.75	6.79	4.438	4.10	0.1	14.87
					0.2	29.74
					0.3	44.61
1976-77	3.969	9.23	0.656	2.05	0.1	7.5
					0.2	15.00
					0.3	22.5
1977-78	2.031	7.05	2.125	3.33	0.1	9.26
					0.2	18.52
					0.3	27.78
1978-79	1.875	6.28	1.00	4.87	0.1	5.04
					0.2	10.08
					0.3	15.12
1979-80	2.094	8.08	3.281	4.87	0.1	9.33
					0.2	18.66
					0.3	27.99
1980-81	1.969	6.41	2.469	3.85	0.1	9.48
					0.2	18.97
					0.3	28.45
1981-82	1.438	3.85	4.563	4.10	0.1	14.87
					0.2	29.74
					0.3	44.61
1982-83	5.313	8.72	2.313	2.95	0.1	13.93
					0.2	27.86
					0.3	41.79
1983-84	2.688	6.92	3.125	4.87	0.1	10.3
					0.2	20.06
					0.3	30.9

APPENDIX A

TABLE 3

SUMMARY OF DATA FOR RECHARGE CALCULATIONS, OBSERVATION WELL 8

RECHARGE PERIOD	ho metres)	to (months)	h_1 (metres)	t_1 (months)	n	R (m/month) x 10^{-2}
1973-74	1.594	8.21	2.438	4.36	0.1	7.53
					0.2	15.07
					0.3	22.60
1974-75	2.438	8.33	1.375	3.21	0.1	7.21
					0.2	14.42
					0.3	21.63
1975-76	1.750	6.67	3.219	3.97	0.1	10.73
					0.2	21.46
					0.3	32.19
1976-77	2.844	9.74	0.250	3.33	0.1	3.67
					0.2	7.34
					0.3	11.01
1977-78	1.031	7.05	1.188	5.13	0.1	3.78
					0.2	7.56
					0.3	11.34
1978-79	1.281	8.85	0.563	3.21	0.1	3.2
					0.2	13.96
					0.3	9.6
1979-80	1.000	7.05	2.156	5.00	0.1	5.73
					0.2	11.46
					0.3	17.19
1980-81	1.250	6.41	1.656	5.38	0.1	5.03
					0.2	10.06
					0.3	15.09
1981-82	0.906	4.10	3.344	4.49	0.1	9.66
					0.2	19.32
					0.3	28.98
1982-83	3.906	9.23	0.969	4.10	0.1	6.59
					0.2	13.18
					0.3	19.77
	1.281	6.54	1.656	5.13	0.1	5.19
					0.2	10.38
					0.3	15.57

Mean annual recharge interval (t_1) = 4.301 months

Recharge as percentage of mean annual precipitation for given storativity

$$= \frac{\text{(mean recharge rate)(mean annual recharge interval)} \times 100}{\text{mean annual precipitation}}$$