82 E/3 #9
Volume 2

MINISTRY OF ENVIRONMENT
WATER MANAGEMENT BRANCH
GROUNDWATER SECTION

OSOYOOS GROUNDWATER
MONITORING PROJECT

1989 MONITORING WELL
CONSTRUCTION PROJECT

MAY 1989

PITEAU ASSOCIATES
GEOTECHNICAL AND
HYDROGEOLOGICAL CONSULTANTS

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PROJECT 89-116

MAY, 1989

PITEAU ASSOCIATES ENGINEERING LTD.

CONTENTS

CONTENTS (cont'd.)

1. INTRODUCTION

1.1 BACKGROUND

Elevated nitrate concentrations are known to exist in groundwater in the South Okanagan Valley. A groundwater monitoring program undertaken in the summers of 1985, 1986, 1987 and 1988 by the Groundwater Section of the British Columbia Water Management Branch determined that nitrate contamination of groundwater in the Osoyoos area was severe and, in many instances, nitrate concentrations in domestic wells exceeded the maximum acceptable concentration for drinking water of 10 mg-N/L (Hodge, 1985b).

In order to obtain additional information on the flow systems and probable sources of contamination in the area, Piteau Associates Engineering Ltd. (PAEL) was requested to construct groundwater monitoring installations in two areas near Osoyoos, and to carry out additional sampling. The scope of the present study was outlined in the original request for proposal conveyed to PAEL in a letter dated December 15, 1988 from Mr. D. Kasianchuk of the Water Management Branch.

1.2 ACKNOWLEDGMENTS

In the course of conducting this study, PAEL has been greatly assisted by a number of people. Messrs. A. Kohut, D. Kalyn and W. Hodge of the Groundwater Section provided information on previous investigations of groundwater quality conducted in the study area. Messrs. L. Miles and S. Toth of the Town of Osoyoos assisted us with locating drilling sites within the Town boundaries, and Mr. J. Cornellisen of the Regional District of Okanagan Similkameen supplied planning information for the area. Information on irrigation and fertilizer

practices was provided by Mr. W. Ross of SOLID, and Mr. T. Watson of the B.C. Ministry of Agriculture.

All assistance received and information obtained was very much appreciated.

1.3 TERMS OF REFERENCE

The Terms of Reference for this project were outlined in Contract No. 91 of the Groundwater Section, Water Management Branch, British Columbia Ministry of Environment, dated Febraury 1989. Acting as prime contractor for the project, PAEL was responsible for the following tasks:

- reviewing all available relevant hydrogeological information for the area.
- locating monitoring installation sites and obtaining access agreements with the present owners.
- contracting and supervising a well drilling contractor to drill holes and install a minimum of 16 piezometers.
- collecting, drying, classifying and bagging representative soil samples from the drillholes. These samples were to be forwarded to the Groundwater Section in Victoria upon completion of the project.
- developing and response testing of piezometers.
- collecting water samples from all piezometers for chemical analyses. Samples were submitted to Analytical Service Laboratories in Vancouver for analysis.
- preparing a final report to summarize the results of the project work and interpretations of collected data.
- maintaining contact with Ministry staff throughout the project.

1.4 PREVIOUS STUDIES

Groundwater quality in the Osoyoos area has been monitored by Groundwater Section personnel since 1983 (Hodge; 1985b, 1986, 1989a, 1989b). This monitoring program involved gathering water samples from a number of sites located around the perimeter of Osoyoos Lake. Most of the samples were analyzed for total nitrite/nitrate-nitrogen, electrical conductivity (EC), pH, hardness, iron, chloride, alkalinity and temperature. In addition, some samples were submitted to the Ministry of Environment laboratory in Vancouver for more detailed inorganic chemical analyses. All sampling has been carried out in the late summer or early fall.

Of the 70 sites sampled and analyzed for total nitrate-nitrogen concentration, using a Hach kit in 1985, 29 showed nitrate concentrations less than detection (0.1 mg/L), 8 were between 0.1 and 3.0 mg/L, 27 were between 3.1 and 9.9 mg/L, and 6 (or 8.6%) had nitrate concentrations greater than 9.9 mg/L. Hodge notes in his report "There appears to be a relationship between the location of the wells within orchards and the levels of nitrate contamination. Many of those wells having high nitrate concentrations are located immediately within orchards." It was concluded that domestic and municipal disposal of sewage effluent to ground was an unlikely source for the nitrate contamination. This followed from the fact that nitrate values were low in areas of little agricultural activity, even though there were many septic tanks in the area, and also because high chloride values (indicative of seepage of sewage effluent) did not accompany high nitrate values. It should be noted that a few of the residents surveyed indicated that they had recently fertilized their lawns, which may also have exacerbated nitrate contamination of local wells.

Similarly in 1986, 1987 and 1988, 86, 40 and 23 sites were sampled and analyzed for nitrate, respectively (see summary on Table I). Of those analyzed in 1986, 1987 and 1988, 29 (17.4%), 13 (32.5%) and 9 (39.1%) had nitrate concentrations above 10 mg/L, respectively.

Of the samples tested in both 1985 and 1986, 21 (46%) samples tested showed increased nitrate concentrations, 13 (28%) remained the same in both years, and only 12 (26%) had lesser values for nitrate concentrations.

Twenty-nine of the sources that were sampled in 1987 had also been sampled in either 1985 or 1986. Twenty three of these sites showed higher nitrate concentrations in 1987 than in previous years. However, some of this apparent increase can be attributed to the fact that Hach test results tend to underestimate the nitrate concentrations, when compared to the laboratory results, which were more available in 1987 and 1988.

2. PHYSIOGRAPHY

2.1 LOCATION

This study was carried out in two separate areas designated A and B, located on the west side of Osoyoos Lake (Figs. 1 and 2). The land in Area A is used mostly for orchards, while land use in Area B is roughly divided equally between orchards and land within the Osoyoos Municipal Boundary, which has been extensively developed. Areas A and B cover approximately 0.77 sq. km. and 1.50 sq. km., respectively.

2.2 TOPOGRAPHY

In both Areas A and B, the land rises towards the west from Osoyoos Lake in a series of kettled terraces (see Fig. 2). Locally on the individual terraces, the ground surface undulates and many water-filled kettles are evident. Generally, the ground surface slopes up relatively steeply from the lake (approx. elev. 275 masl) to a terrace that is approximately 1 km wide at an elevation of about 305 masl. The ground slope steepens again at the western limit of the terrace and rises to elevations exceeding 670 masl. The elevation difference between the western perimeter of each study area and Osoyoos Lake is between 50 to 60 metres.

2.3 CLIMATE

The Osoyoos area lies within a dry region of British Columbia, receiving an average annual precipitation of 336mm. Monthly average values range from 46.8mm in December, to 17.3mm in October. The mean annual air temperature is about 9.7°C at the Osoyoos Climate Station located on the west side of Osoyoos Lake at an elevation of 331 masl. Monthly average extreme temperatures range from -6.1°C in January to 29.1°C in July (see Table II).

Monthly total precipitation for the Osoyoos area is plotted in Fig. 3, and is presented as a series of three graphs. Graph 1 is simply a histogram of monthly precipitation totals for the period of record (1954 to present). Graph 2 shows how the monthly precipitation values deviate from each long term monthly average value. It can be seen, for example, that monthly precipitation since 1984 has generally been below normal.

Graph 3 is used to simplify large collections of data into general dry or wet trends. A rising line on the graph indicates a wetter than average trend as can be seen between 1980 and 1984. Conversely, a falling line shows a drying trend as seen between 1984 and present.

2.4 HYDROLOGY

Osoyoos Lake is the major hydrological feature in the study area. As flow in the Okanagan River is regulated, Osoyoos Lake levels are not controlled by natural flow conditions. Typically, the level in Osoyoos Lake will peak in mid to late June but, under controlled flow conditions, the peak can be delayed until late summer. This was the case during the dry year of 1985 (see Fig. 4). Groundwater levels in the upper bench are much more regular, however, as shown in the water levels for MOE Observation Well 96.

There are little or no expressions of normal surface water drainage in the two study areas.

It is apparent that groundwater levels in the aquifer which underlies the upper bench are not affected by Osoyoos Lake. In contrast, the aquifer which underlies the lower bench (i.e. in the vicinity of Peanut Lake and the Municipal Wells), is likely to be effected by lake levels. However, there are insufficient water level data available to accurately determine the relationship between Osoyoos Lake and the aquifer at these lower locations.

3. DESCRIPTION OF FIELD INVESTIGATIONS

3.1 OFFICE STUDIES AND DRILLHOLE SITING

Office studies carried out as part of this project consisted of gathering and reviewing all available hydrogeological data on the Osoyoos area. In keeping with the major objectives of the study, particular attention was paid to any work done on monitoring of nitrate concentations in groundwater.

Maps and plans of the area showing existing land use and development were reviewed in conjunction with stereo-paired air photographs. This work concentrated on delineating areas of water-bearing surficial sediments and potential sources of nitrogen, e.g. septic tanks, animal feed lots, areas where nitrogeneous fertilizers are applied, etc.

All available water well logs and chemical analyses from Areas A and B were reviewed and locations plotted on area plans.

A site visit was made by Mr. A. Holmes, P.Eng. of PAEL on February 21 and 22, 1989 to meet with Regional District and Municipal personnel, as well as local residents. Potential monitoring sites were chosen and discussed with the Groundwater Section. Sites were selected with a view to developing a series of profiles across each of the two study areas and to locating holes in areas where the aquifer appeared to be deepest. The selected sites are located primarily in the orchard areas; two are near the lake, and none were located upgradient of the orchards.

Once enough suitable drilling sites had been selected and access had been secured, an air rotary rig operated by Field Drilling Ltd. of Aldergrove, B.C. was mobilized to Osoyoos on March 12, 1989. Locations of three sites in Area A and nine in Area B are shown on Fig. 2.

3.2 DRILLING PROGRAM, SOIL SAMPLING AND PIEZOMETER INSTALLATION

Holes cased with 150mm I.D. steel drive pipe were drilled through the sand and gravel unit and approximately 1m into an underlying sandy silt unit. Depending on the saturated thickness available, either one, two or three piezometers were installed at different levels at the site. Three piezometers were installed at site B-1; two piezometers each at sites B-7, B-8 and A-1; and single installations at the other sites. A total of 16 piezometers were completed at 11 sites.

All piezometers were constructed of flush coupled, 50mm schedule 40 PVC pipe, with 1m sections of machine slotted pipe above a nominal 1m long blank section which will serve as a sump. In some instances, screen lengths were increased in the field using a hacksaw. Aqua 8 Monterey sand was used as a filter material around the slotted sections of pipe. This sand was added in approximately 0.6m lifts as the casing was withdrawn from the hole. Depending upon stability of the hole, small quantities of bentonite pellets were placed above the piezometer filter zone. In all holes, bentonite pellets were used as an annular seal around the nominal 3m length of surface casing that was left in each hole. A photograph of a completed well head installation is shown in Photo 1. Detailed drill logs for all holes drilled during the PAEL program are provided in Appendix A. Piezometer completion details are also included on these logs.

Samples were collected and classified at approximately 1m intervals during drilling. Based on the sediments encountered during the drilling program, the lithology of the study areas can be subdivided into two basic units; the medium brown, slightly angular to slightly rounded sand and gravel with trace silt and occasional cobble layers, and the greenish brown sandy silt with trace clay and trace gravel. All soil samples were transported to Vancouver for drying and rebagging before shipment to Victoria.

In Area A, depths to the sandy silt ranged from 9.1m near the shore of Osoyoos Lake, to 4.0m up the hill near Highway 97. Water was encountered only at site

A-1 at a depth of 6.6m. A total of four piezometers were installed in Area A at three sites; only two piezometers had adequate water for development and sampling.

In Area B, the top of the sandy silt unit was encountered at depths ranging from 5.5m to 12.7m below ground, with an average depth of 7.7m. Water levels ranged from 4.4m to 6.7m below ground. A total of twelve piezometers were installed at eight sites in this area and development and sampling was possible in ten of these piezometers.

A complete suite of water levels was measured during the last two days of the field program. A summary of piezometer information is provided in Table III.

3.3 TESTING, SAMPLING AND LABORATORY ANALYSIS

Piezometers were developed using a small air compressor to air lift water out of the hole. If the saturated thickness was inadequate for this method, a Wattera foot valve type pump was used to pump a steady flow of water from the hole. Once the water from the piezometer was of constant temperature, E.C. and low silt content, samples were collected for subsequent chemical analysis in a laboratory. Samples for metals analysis were acidified in the field and the dissolved metals samples were filtered prior to acidification. In addition to the new piezometers, seven other sources were sampled and analyzed using a nitrate Hach kit. All laboratory samples were stored in a cooler and delivered to the ASL laboratory in Vancouver within 48 hours of sampling. A summary of laboratory analyses are presented in Table VIII and the chemist's report is reproduced in Appendix B.

Slug tests were attempted using a Microscout data logger and pressure transducer, but the maximum monitoring frequency of one reading every 10 seconds did not provide sufficient data on which to base hydraulic conductivity value calculations. As response was quicker than the measuring frequency, it is concluded that hydraulic conductivity is greater than 10^{-4} m/s.

4. HYDROGEOLOGY

4.1 SURFICIAL GEOLOGY

The Osoyoos area is underlain by sand and gravel deposits consisting of glacial-fluvial outwash material. The sand and gravel varies in thickness from about 5m to 16m in some local areas. Deposits are designated as kettled outwash immediately adjacent to the lake, and as outwash terraces in the benched area further to the west (Nasmith, 1962). Based on our field observations, the kettled area extends into the eastern portion of the benched area. Many of the kettles have now been filled in by man, or are in the process of being filled, so the present topography is only partially indicative of the natural post-glacial topography.

The sandy silt sediments which underlie the sand and gravel were interpreted to be of lacustrine origin by Nasmith (1962). However, based on the often pebbly nature of the sandy silt which underlies the sand and gravel, and on the observation that the kettles appear to be associated with depressions in the surface of the sandy silt unit below, PAEL believes that these sediments are better classified as a glacial till. Ice blocks which were deposited within this till melted after deposition of the overlying sand and gravel outwash unit, thereby creating the kettled surface which is present today.

The thickness of the sandy silt unit is difficult to determine, as only one of the available well logs encountered bedrock beneath this unit. This hole is located approximately 300m to the west of the boundary of Area B and it shows a sandy silt thickness greater than 19m. The sandy silt unit is in excess of 9m thick in the vicinity of the municipal wells near the Village maintenance yard, and interbedded sand, gravel, silt and clay are known to exist along the western margin of the outwash terrace, in the area near the golf course.

Contours of the surface of the sandy silt unit are shown on Figs. 5 and 6a. These contours are based on depths to the sandy silt unit reported on well logs in the area, and on the depths encountered in the recently constructed monitoring holes. Information on well logs within the study area is summarized in Appendix C. All hole collar elevations were estimated from a 1:5000 topographic contour plan and hence must be considered accurate only to ± 5m.

Contours were drawn by hand around computer posted data points. Hand contouring allowed some interpretation of the data during the contouring process. The resultant contours, therefore, reflect our interpretation of the genesis of the kettles, which has resulted in a number of basins in the surface of the silt/clay unit. This subsurface topography has a very significant effect upon the local groundwater flow, as discussed in the following section.

4.2 GROUNDWATER FLOW

Based on the piezometric levels shown on the sections presented in Figs. 7 and 8, groundwater flow is primarily in an unconfined aquifer located in the base of the glacial outwash unit (saturated sands and gravels) and flow is towards Osoyoos Lake.

During the period of the piezometer installation program, the water table was near the lowest point in the annual cycle (see Fig. 4). The quantity of groundwater flow towards Osoyoos Lake during the winter months is therefore likely to be very small, and probably localized in valley-like depressions in the surface of the sandy silt unit. These depressions exist as either flat lying basins, or abrupt basins associated with kettles. In areas where the surface of the sandy silt unit is locally high, the base of the overlying outwash sediments is often dry in the winter months, as was found in five of the holes drilled during this program. Conversely, near the centre of the depressions, saturated aquifer thickness could be as great as 4m, due to stored groundwater which is effectively contained within the depressions. Estimated contours showing the surface of the water table and saturated aquifer thickness in Area B, during March 1989, are shown on Fig. 6b.

During the summer months, groundwater levels generally rise at least 1.5m within the outwash sediments in response to the large amount of irrigation water that is applied in the orchards (see Fig. 4). These higher groundwater levels saturate the base of the outwash sediments throughout the two study areas, except possibly at localized peaks or ridges in the surface of the sandy silt unit. Groundwater flow towards Osoyoos Lake during periods of high water levels which prevail in the summer months will therefore be at a much greater rate than during the winter months.

An approximate estimate of the summer groundwater flow rate can be made based on the following assumptions:

i) average saturated thickness of sand and gravel near eastern edge of bench is 1.0m
ii) average hydraulic gradient is 5%
iii) hydraulic conductivity of sand and gravel is $3x10^{-4}$m/s

Therefore, groundwater flow towards the lake on a lineal basis is estimated to be about $1.5x10^{-2}$ L/s/m. This estimated groundwater flow rate is compared to recharge rates in the following section.

4.3 GROUNDWATER RECHARGE

As discussed in the previous section, irrigation water is the largest source of recharge to the shallow sand and gravel aquifer which exists in the bench above Osoyoos. Summer water levels rise by as much as 1.5m based on monitoring data, and by as much as 4m based on discussions with local residents regarding the water levels in the many kettles which exist throughout the area. Seasonal change in the water level in these kettles is evident in Photo 2, which shows the March level to be about 1.5m below the level at which the ice formed in January. Mr. Periara, who lives adjacent to this kettle located in the middle of Area A, claims that the level can rise as much as 2.5m above the ice level, i.e. 4m above the water level shown in the photograph, during the irrigation season. However, it is possible that the water level in the kettle would be partially perched above the groundwater table.

The quantity of irrigation water that is applied to orchards in the area is estimated to be about 1.6 L/s/Ha (414 mm/mo) based on approximate unit consumption for the area (W. Ross, SOLID, pers. comm.). Evidently, the system was sized to provide approximately 18% more water than the estimated irrigation demand, based on normal irrigation practice. According to Mr. Ross, this excess capacity is utilized each year.

PAEL carried out a soil water balance calculation to estimate the probable excess quantity of irrigation water which would be available for groundwater recharge. Parameters used included lake evaporation (Department of Transport, June 1967), a soil water holding capacity of 122mm/1.2m (Tim Watson, pers. comm.), and an estimate of transpiration equivalent to the pan evaporation (i.e. total evapotranspiration from orchard is twice pan evaporation).

The soil water balance calculation is presented in Table IV, and indicates that surplus irrigation water, during the growing season, ranges from 83.8mm/mo to 236mm/mo for an average of 144mm/mo. This represents approximately 35% of the total irrigation water applied. Applying this surplus as groundwater recharge to a 1m wide strip running for 500m across the bench (perpendicular to the lake) indicates that average recharge during the growing season could be on the order of 2.8×10^{-2} L/s/m. This is almost twice the estimated rate of groundwater flow towards the lake (Section 4.2), however, when the volume of groundwater in storage, beneath the rising water table is deducted, the net groundwater flow is close to the 1.5×10^{2} L/s/m value estimated in the last section.

The above calculations demonstrate that infiltrating irrigation water is by far the most important source of recharge to groundwater in the shallow aquifer below the study areas. The only exception to this is for high capacity Town of of Osoyoos and SOLID wells, installed near Osoyoos Lake, which may induce some recharge from the lake. Irrigation water, and any nutrients it may contain, will therefore have a very significant impact on the quality of groundwater abstracted upgradient of the lake in the study area. Sources of nutrients in the irrigation water are discussed in the following section.

5. NITRATE DISTRIBUTION

5.1 POTENTIAL SOURCES OF NITROGEN

Causes of elevated nitrate concentration in groundwater have been studied in many areas of the world, and sources have generally been attributed to animal wastes, agricultural fertilizers, domestic fertilizers and septic tanks (Gormly et al, 1979; Flipse et al, 1984; Schmidt, 1972; Hill 1982; Porter, 1980). A review of current land use in the study area showed that the most likely sources of the nitrate observed in groundwater were fertilizers applied to orchards, fertilizers applied to lawns, septic tanks and the spray irrigation system used to dispose of municipal effluent. The Osoyoos spray irrigation scheme is located upgradient and mostly south of Study Area B (Fig.2). Hence, except for the southern tip of Area B, it should not have a large impact on the groundwater quality. The significance of all other potential sources are discussed quantitatively in the following section.

5.1.1 Agricultural Fertilizers

Fertilizers are applied to orchards at varying rates. Apple orchards generally receive little or no fertilizer, soft fruits are fertilized annually with up to 260 kg of fertilizer per hectare and fertilizer is applied to cherry orchards at rates of up to about 500 kg/Ha (Watson, 1989). Typical fertilizers are 34-0-0 or 36-0-0 (urea), hence nitrogen represents about one third of the total mass of fertilizer applied. Based on the above application rates, annual estimated nitrogen applications to orchards are as follows:

Apple orchards - minimal nitrogen
Soft fruit orchards - 50 to 90 kg-N/Ha
Cherry orchards - 100 to 180 kg-N/Ha

As the total area of orchards in Study Areas A and B amounts to 83 Ha and 92 Ha respectively, total annual nitrogen application could amount to 5810 kg in Area A, and 6440 kg in Area B, assuming each of the three types of orchards account for approximately one third of the orchard area. Soil water balance calculations discussed in Section 4.3 indicated that 35% of irrigation water eventually seeps to the watertable. After allowing for some nitrogen losses as a gas released to the atmosphere, it is reasonable to assume that this water will transport about 20% of the fertilizer nitrogen to the watertable. If 20% of the nitrogen applied to the orchards is leached to the watertable, total contribution of nitrogen to the receiving groundwater would be approximately 1162 kg in Area A, and 1288 kg in Area B.

5.1.2 Lawn Fertilizers

Fertilizing of lawns can contribute as much as 500g of nitrogen per $100m^2$ of lawn to shallow water tables (Porter 1980). Assuming that each home in Area A on the upper bench, (approximately 34 homes) and each home in Area B west of HWY 97 (approximately 55 homes) has $800m^2$ of surrounding lawns, and that these lawns are fertilized bi-annually, total nitrogen application could amount to 136 kg in Area A, and 220 kg in Area B. This is a relatively minor source of nitrogen when compared to that quantity of nitrogen applied to the orchards. Thus, nitrogen from this source could impact on the quality of wells located immediately adjacent to lawns, but the impact is not likely to be as severe or as widespread as for agricultural fertilizers.

5.1.3 Septic Tanks

Nitrogen in domestic effluent issuing from a septic tank is generally in the ammonia form. Up to 50% of the nitrogen in domestic effluent can be removed from the septic tank and infiltration system by volatilization.

Conversion of the remaining ammonia to nitrate occurs under the oxidizing conditions in the drainfield.

Average nitrogen concentration in domestic effluent is 61 mg/L (Porter 1980), and approximately 50% of this nitrogen is lost before the effluent percolates down to the water table (Andreoli et al, 1977; Bro, 1980). Based on an average per capita effluent flow of 200 L/day, and an average nitrate concentration of 30mg-N/L in effluent which reaches the water-table, nitrogen loading from 102 persons in Area A (34 homes) and 165 persons in Area B (55 homes) would be 219 kg and 365 kg, respectively. As with lawn fertilizers, this is clearly a less significant source than agricultural fertilizers, but a source which will be considered nonetheless.

5.1.4 Other Sources

The other principal source of nitrogen to groundwater in the study areas is the irrigation water itself. This water typically has a nitrate concentration of about 0.5 mg-N/L, hence any other nitrogen sources must be considered to be cummulative over and above this initial nitrogen level.

5.2 PREDICTED NITRATE LEVELS

Based solely on nitrogen derived from agricultural fertilizers in the study area, the average nitrate concentration in groundwater can be predicted, as follows:

Average N application rate in orchards = 70kg-N/Ha
Average rate of irrigation water application = 1.6 L/s/Ha
Total quantity of irrigation water applied in growing season (5 months) = 20.7 x 10^6 L/Ha
Assuming total nitrogen contained in fertilizer is dissolved in applied irrigation water, then average nitrate concentration = 3.4 mg-N/L

Add nitrate already dissolved in irrigation water = 0.5 mg-N/L

Estimated aqriculture sourced Nitrate concentrations in groundwater = 4 mg-N/L

Nitrate from domestic sources (lawns and septic tanks) is estimated to equal about 50% of the nitrate from agricultural fertilizers, hence average nitrate concentration in groundwater in the study area is expected to be about 6 mg-N/L based on the assumptions and calculations discussed above.

5.3 GROUNDWATER CHEMISTRY

5.3.1 Inorganic Chemistry

Inorganic chemistry results for samples collected in the summer of 1987 and the winter of 1989 are summarized on Tables V and VI, respectively. Both sets of data indicate that local groundwater is moderately alkaline and is dominantly a calcium bicarbonate water, although magnesium, sodium and sulphate are also present at very significant concentrations. Chloride is typically present at concentrations in excess of 10 mg/L, with a maximum concentration of 47.9 mg/L noted near the shore of Osoyoos Lake, between Areas A and B (Table V). These chloride concentrations are greater than would be expected for the natural chemistry of groundwater in the area, and indicate that the quality has been significantly impacted by human activities. Whether the chloride originates from road salt, septic effluent or other sources is not known at this time.

With the exception of pH, which was generally almost one unit higher in the summer samples then in the winter samples, there were no obvious variations in the groundwater chemistry on a seasonal basis. The pH difference may be attributable to some shift which can take place between the time of sampling and the lab analysis, or possibly to the difference in the chemistry of the irrigation water which is the source of summer recharge, and local precipitation which is the source of recharge in the non-growing season.

5.3.2 Distribution of Nitrogen

Nitrate concentrations measured in water sampled from wells, piezometers and ponds in the study area are posted on Fig. 2. Values measured in the summer of 1987 and the winter of 1989 are shown. The nitrate concentrations vary considerably from sampling point to sampling point, indicating that there is no uniform or dominant single source of nitrogen in the area, but rather a very non uniform source of nitrogen over virtually the entire area.

Average nitrate concentrations of all the samples taken in the winter of 1989 is 11.2, which is about twice the average value predicted in Section 5.2. The average is based on only twelve samples, so is not considered to be truly representative of the average nitrate concentration in groundwater, but it does indicate that the sources of nitrogen discussed in Section 5.1 may have been underestimated.

Although there is no obvious pattern to the overall distribution of nitrate concentrations posted on Fig. 2, there are some apparent consistencies in the data, as listed below:

i) Samples collected from the ponds have low nitrate concentrations. This observation appears to hold true for all samples collected from ponds since 1985. It is possible that surface water runoff, which may not have had time to dissolve nutrients, forms a large proportion of the water stored in these ponds.

ii) Except at piezometer site B-1, which is located in a deep portion of the aquifer, underlying the lower bench near Peanut Lake, there is no obvious variation in nitrate concentration with depth. However, there is a very pronounced variation at Site B-1 suggesting that, during winter months, the shallower, locally recharged groundwater has a much lower nitrate concentration than deeper groundwater. Groundwater probably resides in the deeper portions of the aquifer for long periods, and is representative of long term average water quality, whereas shallow groundwater may show some seasonal variation with ambient recharge. At the B-1 site, the aquifer is in hydraulic connection with Osoyoos Lake, hence observed nitrate concentrations at depth may also be a function of dilution with lake water. Further sampling is required before the relationship between depth and nitrate concentration can be determined in different parts of the study area, and during different seasons.

Most of the nitrate concentrations measured during the March 1989 sampling program were greater than 10 mg-N/L. As most of the samples were collected within or near orchards, fertilizers applied to orchards appear to be the most likely nitrogen source. Measured nitrate concentrations ranged from 27.5 mg-N/L in an orchard near the west edge of Area B to the 0.1 mg-N/L sample collected from the shallow piezometer located beside Peanut Lake. The lowest nitrate concentration measured in one of the new piezometers that was installed within an orchard was 7.5 mg-N/L, at site A-1, located in the east corner of Area A.

5.3.3 Long Term Trends in Nitrate Concentrations

There is very little information available regarding nitrate concentrations in the area over the long term. Data which are available are summarized on Table VII.

Nitrate concentrations measured in the Osoyoos Town wells have not shown any noticeable increase since 1973. Similarly, nitrate concentrations measured in MOE Observation Wells No's. 96 and 97 show considerable variation from year to year, but do not show any discernible upward trend. On the other hand, MOE Observation Well No's. 92 and 93, which were installed at a site near the new B-8 installation, indicated nitrate concentrations of less than 1 mg-N/L in 1969 (Hodge 1985(a)). The recent samples collected from B-8, P1 and P2, indicate nitrate concentrations are now in the 13 mg-N/L range. Increases of the same and even greater magnitude, over the same period, have been noted at MOE Observation Well No's 100, 101 and 102, located about 1.5 km northwest of Area A (based on recently available 1988 sampling results).

It is apparent that in some areas, groundwater nitrate concentrations have remained relatively constant over the last 15 to 20 years, while in other areas (all in orchards), the limited data suggest that groundwater nitrate concentrations have probably fluctuated significantly from season to season and year to year, and that there may have been an overall increase in some areas. Any increase is likely to be caused by changing cultivation practices in the surrounding orchards. However, further research is required before these trends and causes can be clearly defined.

The relatively constant nitrate concentrations observed in the Osoyoos Town wells may be attributable to their location (see Fig. 2) near the discharge area of the groundwater flow system. The groundwater quality represents average conditions in the recharge area, and may not be greatly affected by changing conditions in a number of smaller areas. Nitrate concentration in the Osoyoos well water is also moderated to some extent by mixing of local groundwater with lake water that is induced to flow into the aquifer. As demand for municipal water has probably increased over the years, the proportion of induced lake water recharge has probably increased as well. This would tend to reduce nitrate concentrations slightly, thus a constant nitrate concentration in well water could still indicate a slight degradation of the local groundwater quality.

6. CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

6.1.1 Hydrogeology

A discontinuous and relatively thin (up to 12m thick) deposit of outwash sand and gravel covers most of the surface in the study area. The basal portion of the sand and gravel is generally saturated due to the low permeability sandy silt till which underlies the outwash deposits and restricts downward flow of water. This perched water table aquifer has historically been used as a source of domestic water, and is still used by a number of families in the two study areas.

Infiltrating irrigation water represents the greatest source of groundwater recharge to the perched water table, hence groundwater levels peak during the late summer. During the winter months, groundwater recharge is minimal, and the water table is typically about 1.5m lower than during the growing season. Many zones in the sand and gravel aquifer are completely unsaturated during the winter, but some reservoirs of stored groundwater remain within the saturated sand and gravel unit, contained in depressions in the surface of the sandy silt unit. These basins generally are seen on surface as the many kettles which exist in the area.

6.1.2 Nitrogen Analyses

Nitrogen in groundwater is virtually all in the form of nitrate, with only low concentrations of NH_3 and TKN (i.e. ammonia and organic nitrogen).

Hach Kit analyses are useful for preliminary work; however, it appears that these tests tend to underestimate nitrate concentrations, and that it is important to run laboratory analyses where nitrate concentrations are high, and were an absolute value is needed.

6.1.3 Nitrogen Sources

Nitrate in groundwater in the study area is apparently from three main sources. Nitrogen which is leached from fertilizer applied to the orchards is the principal source. Excess irrigation water transports the leached nitrogen to the water table. The other two sources are septic tanks and fertilizers applied to lawns, but these are generally not as significant as the agricultural fertilizers. Quantitative estimates of the total nitrogen leached, together with estimated groundwater recharge, were used to calculate approximate average nitrate concentrations in groundwater beneath the eastern perimeter of the study area. The calculated average nitrate concentration of 6 mg-N/L appears to be too low when compared with many of the water samples collected from within the orchards. Many of these samples exceeded the 10 mg-N/L nitrate concentration that is the recommended maximum acceptable limit for drinking water in Canada. Samples collected from the Osoyoos Town wells and piezometers P1 and P2 at Site B-1 indicate that the 6 mg-N/L estimate may be reasonable for an overall average concentration of nitrate in groundwater near Osoyoos Lake. However, groundwater at these locations is probably affected by the chemistry of Osoyoos Lake water, which is induced to recharge the aquifer whenever the Osoyoos Town wells or the new SOLID well are pumped.

Available long term data only goes back as far as 1969, and is limited to a few MOE Observation wells and the Osoyoos Town wells. Based on a review of data from the Osoyoos Town wells, nitrate concentrations have not changed appreciably since 1973. However, there have been some temporal increases in nitrate concentrations in groundwater at some of the MOE Observation well sites, indicating that fertilizer application rates may have changed from time to time in different areas.

Due to the shallow nature of the groundwater flow system and the relatively small volume of storage available in the aquifer which underlies the orchard-covered bench areas above the Town of Osoyoos, nitrate concentrations, at any given time, are likely to be indicative of current and very localized cultivation practice.

6.1.4 Future Trends

As cultivation practices are not expected to trend towards increased fertilizer application rates, nitrogen from this source should remain the same or possibly decrease in the future. Average nitrate concentrations in the groundwater within the study areas should therefore remain at or near the present level, with superimposed seasonal fluctuations. However, increased population and an expansion of the existing spray-irrigation sewage effluent treatment plant could cause further increases in nitrate concentrations in groundwater located to the east of the golf course, at the extreme south of Area B.

6.2 RECOMMENDATIONS

Prior to collecting the next suite of samples from the new monitoring installations, all piezometers that were not sampled in March 1989 should be developed with air. Additional development should also be done on A-1 P2, B-4 P1, B-5 P1, B-7 P2, B-8 P2 and B-9, as development in these piezometers was limited by low water levels.

Two 32mm Waterra sampling footvalves have been provided to collect samples from the new piezometers. One 19mm foot valve has also been provided to sample a 19mm standpipe installed above the winter water table at site B-7.

Some attempt should be made to correlate the type of orchard to groundwater nitrate concentration. A correlation may exist between cherry orchards and high nitrate concentrations or apple orchards and low nitrate concentrations.

Consideration should be given to installing some monitoring wells in the area west of the existing orchards, to enable monitoring of upgradient trends. This would require careful site selection to ensure that the shallow sand and gravel aquifer which is present under the orchards, is also present at the proposed monitoring site. Consideration could be given to running an electromagnetic geophysical survey to help delineate the shallow aquifer at potential monitoring well sites.

As there is evidence that there might be considerable seasonal variation in the groundwater quality, monthly sampling and analysis of nitrate, TKN and a few other parameters such as EC, chloride, and pH, and temperature could be considered for a few selected wells.

Respectfully submitted,
PITEAU ASSOCIATES ENGINEERING LTD.

Andrew Holmes

Andrew T. Holmes, P.Eng.

Paul R.

Paul R. Madsen, P.Eng.

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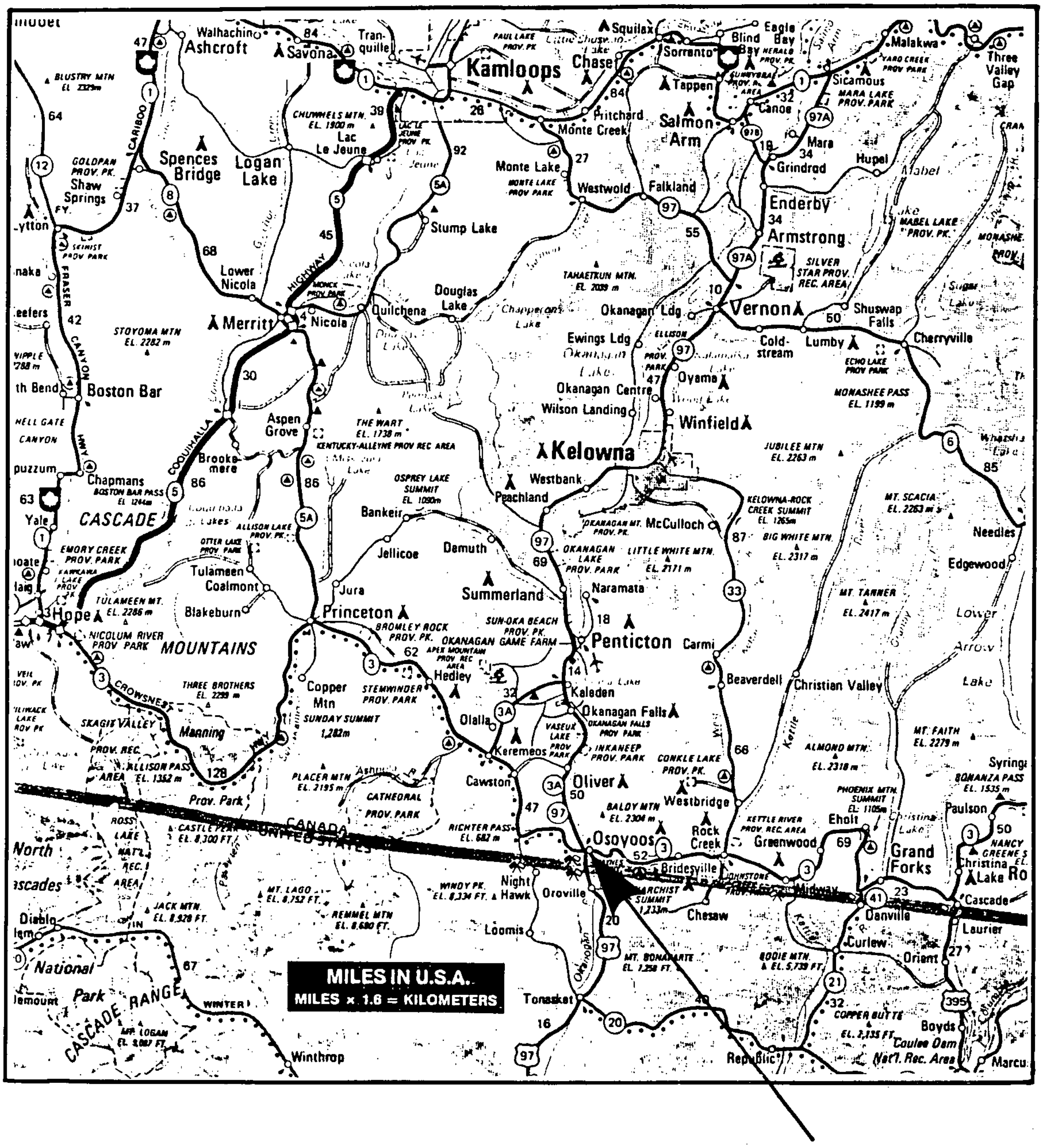
JOB NUMBER



STUDY AREA

FIG. 1

MINISTRY OF ENVIRONMENT
GROUNDWATER SECTION

PITEAU ASSOCIATES
GEOTECHNICAL CONSULTANTS
VANCOUVER CALGARY

OSOYOOS GROUNDWATER
MONITORING PROGRAM
OSOYOOS , B.C.

SITE LOCATION PLAN

BY: PRM

DATE: APR 89

APPROVED: AH

DWG:

JOB NUMBER

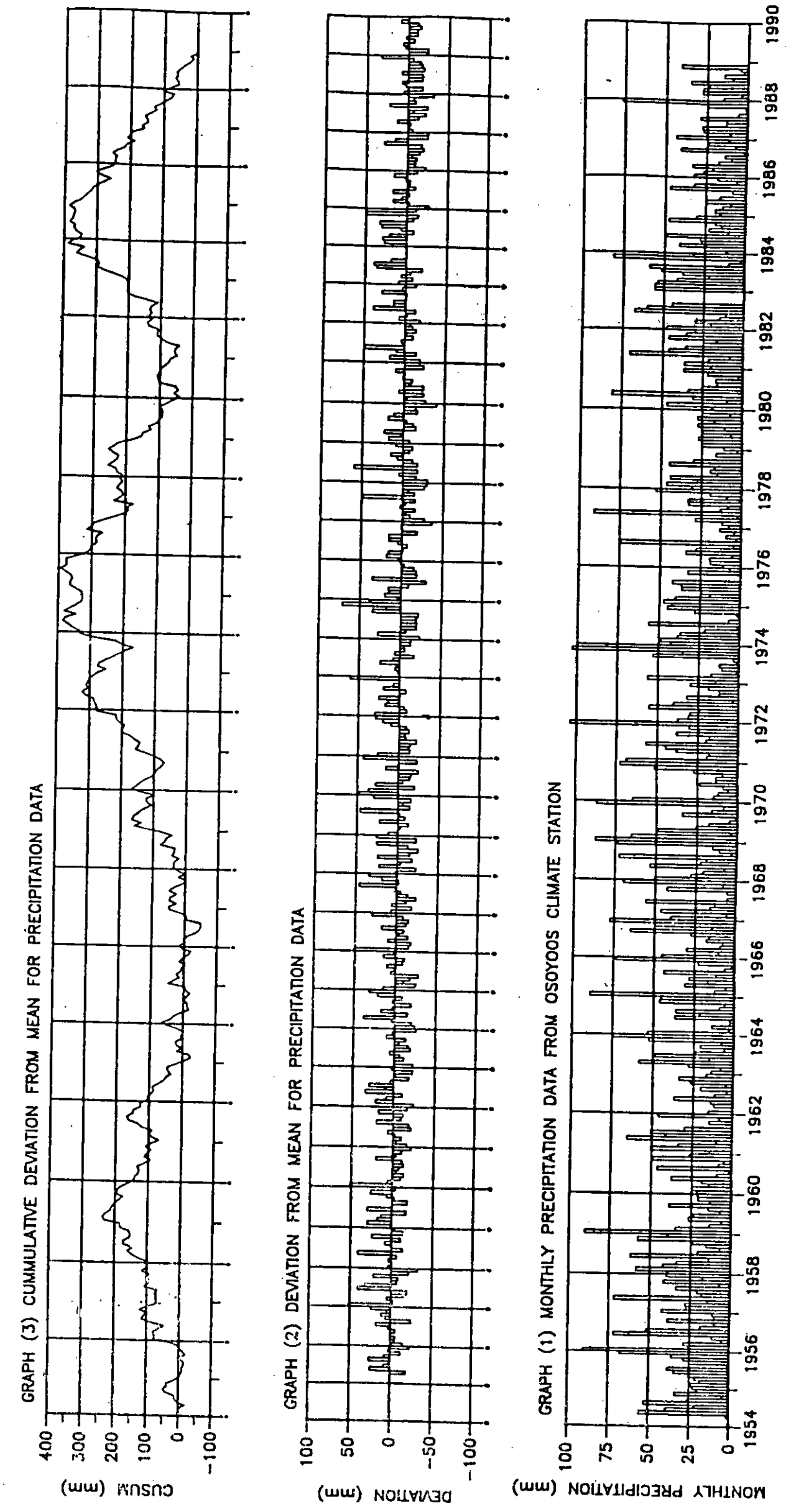


FIG. 3

MINISTRY OF ENVIRONMENT
GROUNDWATER SECTION

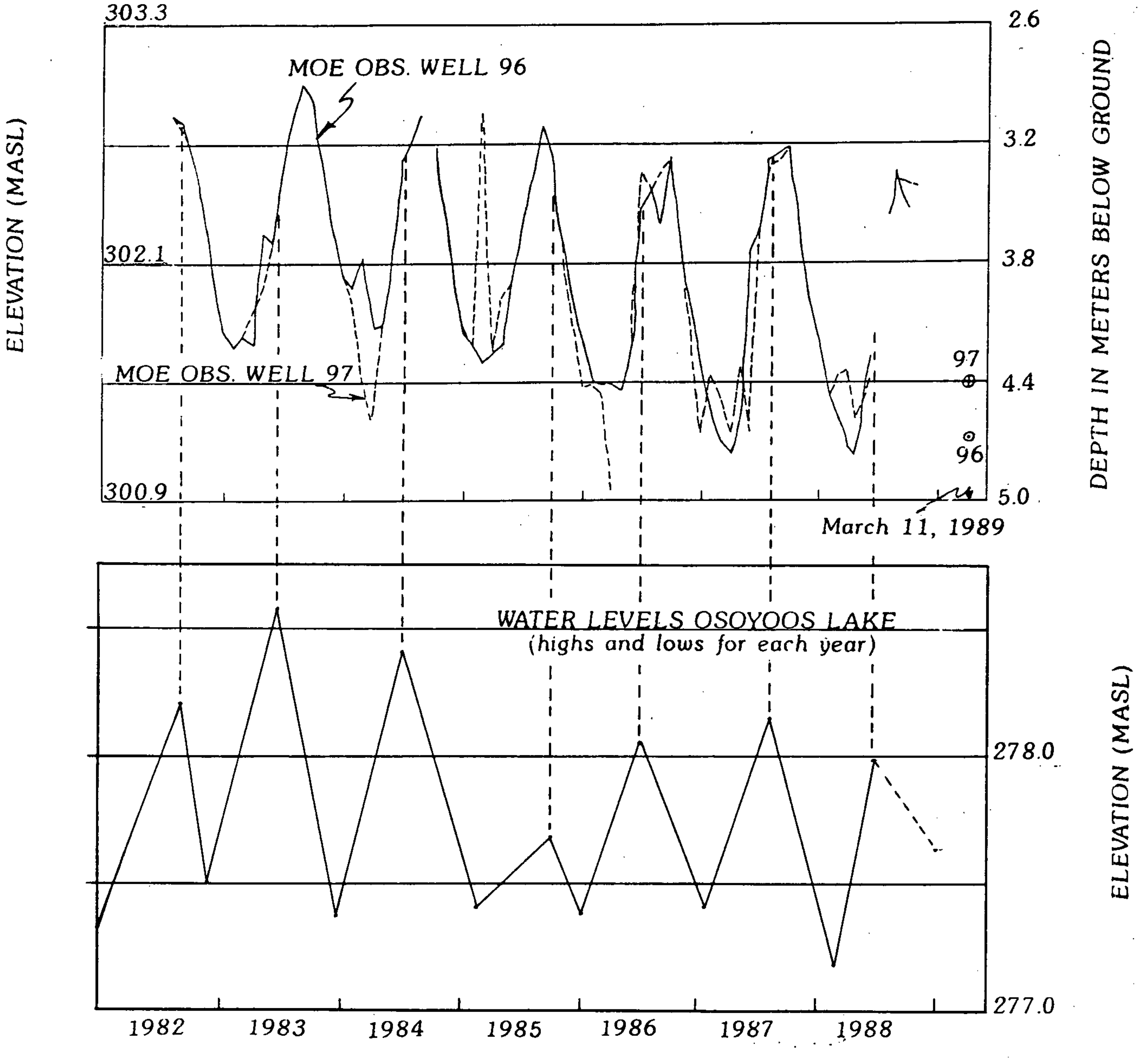
PITEAU ASSOCIATES
GEOTECHNICAL CONSULTANTS
VANCOUVER CALGARY

OSOYOOS GROUNDWATER
MONITORING PROGRAM
OSOYOOS, B.C.

PRECIPITATION TRENDS IN OSOYOOS AREA

BY: PRM	DATE: APR' 89
APPROVED: QH	DWG:

JOB NUMBER



NOTE: SEE LOCATIONS OF MOE OBS. WELLS 96 AND 97 ON FIG. 6

FIG. 4

MINISTRY OF ENVIRONMENT

GROUNDWATER SECTION

PITEAU ASSOCIATES
GEOTECHNICAL CONSULTANTS
VANCOUVER CALGARY

OSOYOOS GROUNDWATER
MONITORING PROGRAM
OSOYOOS, B.C.

OBSERVATION WELL AND
LAKE HYDROGRAPHS

BY: PRM	DATE: APR 89
APPROVED:	DWG: 1

JOB NUMBER

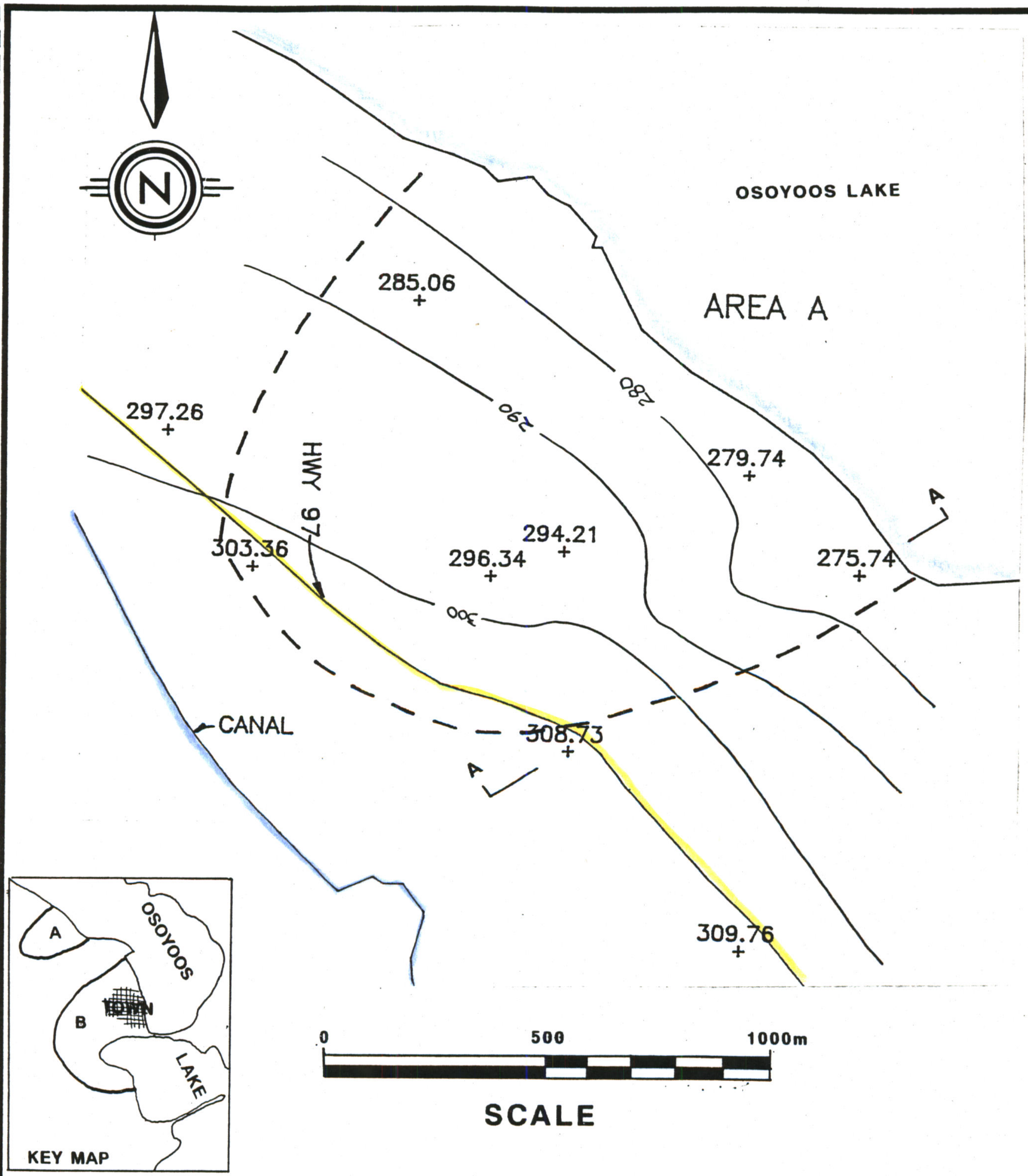


FIG.5

NOTE: THE WATER LEVELS USED IN THIS INTERPRETATION WERE MEASURED DURING THE WINTER

MINISTRY OF ENVIRONMENT
GROUNDWATER SECTION

PITEAU ASSOCIATES
GEOTECHNICAL CONSULTANTS
VANCOUVER CALGARY

OSOYOOS GROUNDWATER
MONITORING PROGRAM
OSOYOOS, B.C.

ELEVATION OF TOP OF
SANDY SILT IN AREA A

BY: PRM

DATE: APR 89

APPROVED:

DWG:

TABLE I

SUMMARY OF NITRATE CONCENTRATIONS IN GROUNDWATER SAMPLED IN OSOYOOS AREA BY MOE: IN SUMMERS OF 1985 TO 1987

SAMPLING[3] YEAR	NO. OF[4] SITES	TOTAL NITRATE-NITROGEN[1] CONCENTRATION IN WATER (mg/L)				UNSAFE FOR[2] DRINKING (%)
		LESS THAN 0.1	0.1 to 3	3.1 to 9.9	GREATER THAN 10	
1985	70	29	8	27	6	8.6
1986	86	27	19	25	29	17.4
1987	40	0	8	29	13	32.5
1988	23	0	2	12	9	39.1

NOTES:

1. All water samples were analyzed for total nitrate-nitrogen. Most analyses during 1985-86 were performed using a colourmetric method (Hach Kit), while most of the analyses in 1987-88 were performed in a laboratory.

NO! nitrate-nitrogen

2. Canadian Drinking Water guideline requires nitrate concentration to be less than 10 mg/L.

3. Data abstracted from Hodge, 1985b, 1986, 1989(a) and 1989(b).

during

4. Only a few of the sites anlayzed duirng 1985-86 were in Study Areas A and B. Approximately one-third to one-half of the sites analyzed during 1987-88 were in Study Areas A and B.

TABLE II

CLIMATE DATA

OSOYOOS
49° 4′N 119° 31′W 331 m

	JAN JAN	FEB FÉV	MAR MAR	APR AVR	MAY MAI	JUN JUIN	JUL JUIL	AUG AOÛT	SEP SEPT	OCT OCT	NOV NOV	DEC DÉC	YEAR ANNÉE
Daily Maximum Temperature	–0.6	4.0	10.0	16.5	21.5	25.2	29.1	27.8	22.4	14.8	6.2	1.4	14.9
Daily Minimum Temperature	–6.1	–3.1	–0.2	3.8	8.4	12.4	14.9	14.2	9.7	4.4	–0.1	–3.5	4.6
Daily Temperature	**–3.4**	**0.5**	**4.9**	**10.2**	**15.0**	**18.8**	**22.0**	**21.0**	**16.1**	**9.7**	**3.1**	**–1.0**	**9.7**
Standard Deviation, Daily Temperature	3.0	2.6	1.6	1.1	1.5	1.5	1.2	1.6	1.6	1.1	1.9	2.2	0.7
Extreme Maximum Temperature	11.7	14.4	23.3	30.6	34.4	36.7	39.5	37.2	33.9	26.0	20.0	14.5	39.5
Years of Record	26	26	26	27	27	27	27	27	27	26	27	27	
Extreme Minimum Temperature	–25.0	–22.0	–17.8	–6.7	–3.9	0.6	5.6	5.6	–2.2	–5.6	–18.3	–25.6	–25.6
Years of Record	26	26	26	27	27	27	27	27	27	26	27	27	
Rainfall	15.9	19.9	20.1	20.0	32.5	30.8	19.3	26.9	18.4	17.1	22.2	22.8	265.9
Snowfall	25.2	9.7	2.4	0.0	0.0	0.0	0.0	0.0	0.0	0.2	7.8	24.1	69.4
Total Precipitation	**41.2**	**30.0**	**22.5**	**20.0**	**32.5**	**30.8**	**19.3**	**26.9**	**18.4**	**17.3**	**30.0**	**46.8**	**335.7**
Standard Deviation, Total Precipitation	26.8	18.0	12.2	15.9	24.5	17.4	15.6	20.5	16.8	13.1	21.6	28.0	59.3
Greatest Rainfall in 24 hours	21.1	24.1	17.8	18.8	39.1	27.4	30.2	19.3	28.4	23.6	16.5	22.9	39.1
Years of Record	26	25	26	27	27	26	27	27	27	26	26	27	
Greatest Snowfall in 24 hours	22.9	34.0	14.7	T	0.0	0.0	0.0	0.0	0.0	3.8	15.7	25.4	34.0
Years of Record	26	26	26	27	27	27	27	27	27	26	27	27	
Greatest Precipitation in 24 hours	22.9	40.9	17.8	18.8	39.1	27.4	30.2	19.3	28.4	23.6	16.5	25.4	40.9
Years of Record	26	25	26	27	27	26	27	27	27	26	27	27	
Days with Rain	4	5	6	6	7	7	5	6	5	6	7	6	70
Days with Snow	7	3	1	0	0	0	0	0	0	*	2	6	19
Days with Precipitation	10	8	7	6	7	7	5	6	5	6	9	11	87

From Enviroment Canada, 1981

TABLE III

SUMMARY OF MONITORING INSTALLATIONS

SITE	PIEZO. NO.	DESCRIPTION[1]	CASING STICKUP (m)	PIEZO. DEPTH FROM TOP OF COLLAR (m)	WATER LEVEL FROM TOP OF COLLAR (m)	DEVELOPED[2] AND SAMPLED	DEPTH TO CLAY (m)	APPROX. COLLAR ELEV. (m)
A-1	P1	South end of Area A	0.88	11.11	7.44	Y	9.14	284.9
	P2	South end of Area A		9.74	7.44	Y		
A-2	P1	CPR right-of-way	0.69	7.64	n/a	N	5.95	285.7
A-3	P1	A. Gaspar property, Hwy. 97 South	0.69	5.65	n/a	N	3.96	312.7
B-1a	P1	South end of Peanut Lake	0.65	14.02	5.24	Y	13.71	287.7
B-1b	P2	South end of Peanut Lake	0.57	11.14	5.19	Y		287.6
	P3	South end of Peanut Lake		9.18	5.19	Y		
B-3	P1	North end Elks parking lot	0.66	7.95	n/a	N	6.40	307.7
B-4	P1	End of 70th Avenue cul-de-sac	0.65	6.90	5.05	Y	5.50	304.7
B-5	P1	West end of 74th Avenue	0.93	7.82	6.42	Y	6.10	305.9
B-6	P1	Cul-de-sac beside police station	0.89	8.66	n/a	N	7.00	305.9
B-7[3]	P1	In orchard on 103rd Street by trailer	0.70	11.40	7.44	Y	9.90	304.7
	P2	In orchard on 103rd Street by trailer		9.40	7.44	Y		
B-8	P1	Pfingstfag property near Elks Lodge	0.95	8.16	5.98	Y	6.40	305.0
	P2	Pfingstfag property near Elks Lodge		7.05	5.98	Y		
B-9	P1	Behind Kobau Bowling Alley	0.62	7.74	6.25	Y	6.71	305.6

NOTES:
1. See Fig. 2 for locations of monitoring installations.
2. Y = Yes; N = No because no water available in piezometer.
3. A third 19mm dia. sched.40 PVC piezometer was installed in B-7.

TABLE IV

SOIL WATER BALANCE

ASSUMED WATER HOLDING CAPACITY (mm) = 122

	J	F	M	A	M	J	J	A	S	O	N	D	TOTALS (mm)
TEMP (C)	-3.4	0.5	4.9	10.2	15	18.8	22	21	16.1	9.7	3.1	-1	
PRECIP + IRR	41.2	30	22.5	116.6	414	414	414	414	414	17.3	30	46.8	2374.4
EVAP + TRANSPIRATION	7.6	7.6	10.2	81.3	279.4	325.2	330.2	238.8	177.8	50.8	10.2	7.6	
DEFICIT	0	0	0	0	0	0	0	0	0	33.5	0	0	
SURPLUS	33.6	22.4	12.3	35.3	134.6	88.8	83.8	175.2	236.2	0	0	25.5	847.7
STORAGE	122	122	122	122	122	122	122	122	122	88.5	108.3	122	
CHANGE	0	0	0	0	0	0	0	0	0	-33.5	19.8	13.7	

COMMENTS

1. EXCEPT WHERE INDICATED, ALL VALUES IN THE ABOVE TABLE ARE IN mm.
2. THE WATER HOLDING CAPACITY (STORAGE) IS DETERMINED AS FOLLOWS
   WHC = 1.2"/FT * 4' SOIL = 4.8" (122 mm)
3. EVAP = MEAN MONTHLY LAKE EVAPORATION AS DETERMINED FROM
   CANADA-DEPARTMENT OF TRANSPORT; METEOROLOGICAL BRANCH, CLIMATIC MAPS
4. DURING NON-GROWING SEASON; EVAP + TRANSPIRATION = LAKE EVAPORATION (APPROX.)
5. DURING GROWING SEASON (MAY-SEP); EVAP + TRANSPIRATION = 2X LAKE EVAPORATION (APPROX.)

TABLE V
SUMMARY OF CHEMISTRY DATA FROM IMMEDIATE STUDY AREA (SUMMER,1987)

					MAJOR IONS (DISSOLVED) (mg/L)							NUTRIENTS (mg/L)					
	WELL OWNER	ADDRESS	pH	COND. (uS/cm)	Ca	Mg	K	Na	ALK (Tot)	SO4	CL	NO3	NO2	NH3	TKN	N (Tot)	P (Tot)
AREA A	F.HOSTA	12202 HIGHWAY 97	7.8	630	78.4	17.5	4.0	16.5	206	50.6	16.7	10.2	<0.005	<0.005	.15	10.4	.145
	R.PEEL	10815 81st St	8.6	857	112	27.1	4.4	18.6	295	55.3	8.4	23.6	<0.005	<0.005	.30	23.9	.008
	J.L.WIGHT	10405 81st St	7.8	1000	NA	NA	6.1	25.1	354	86.5	15.5	17.4	<0.005	.02	.58	18.0	.081
BETWEEN AREA A & AREA B	A.J.TRUDEL	9409 79th St	8.5	750	106	17.9	4.8	17.3	200	59	14.2	26.6	<0.005	<0.005	.13	26.7	.036
	E.SLINGSBY	9419 79th St	8.6	900	NA	NA	5.7	43.7	237	65.6	47.9	8.86	<0.005	<0.005	.14	8.94	.016
	MANTLES	9417 79th St	8.5	1200	NA	NA	6.0	49.8	438	138	44.1	5.55	<0.005	<0.005	.61	6.16	.022
	NUNDEL	9405 79th St	8.5	650	NA	NA	4.4	20.2	220	58.7	12.5	8.98	.017	<0.005	.12	9.12	.049
AREA B	DUMONT AUTO	93rd ST	8.5	700	96.2	15.0	4.5	25.5	238	48.3	12.6	14.0	<0.005	<0.005	.20	14.2	.155
	D.McDERMID	6806 HIGHWAY 97	8.7	285	NA	NA	2.5	11.2	114	29.8	3.4	<0.02	<0.005	.009	.23	.25	.013
	E.J.LANG	2803 89th St	8.5	600	NA	NA	4.1	18.6	207	41.9	13.2	10.6	<0.005	<0.005	.03	10.7	.213
	L.MARTINS	107th St	8.4	940	NA	NA	6.0	44.1	249	165	20.7	12.2	<0.005	<0.005	.14	12.3	.04

From Hodge, February 1989(2)

TABLE VI

SUMMARY OF INORGANIC CHEMISTRY DATA (MARCH 1989)

SITE	pH	COND. (us/cm)	MAJOR IONS (DISSOLVED) (mg/L)							NUTRIENTS (mg/L)						
			Ca	Mg	K	Na	ALK (Total)	SO_4	Cl	NO_3	NO_2	NH_3	TKN	N (Total)	P (Total)
A1 P1	7.72	638	73.6	28.5	4.27	19.3	272	49.1	11.4	7.50	<0.001	<0.005	0.20	7.70	0.13
A1 P2	7.69	640	72.9	29.7	4.20	17.8	280	45.9	11.1	9.49	0.01	<0.005	0.34	9.84	1.12
A2															
A3															
B1 P1	7.63	591	82.7	17.5	4.46	18.5	263	33.2	10.0	6.79	0.01	<0.005	0.25	7.05	0.09
B1 P2	7.61	505	74.8	14.8	3.40	15.3	232	45.1	13.0	3.00	<0.001	<0.005	0.24	3.24	0.12
B1 P3	7.77	471	58.3	21.3	5.46	16.6	219	46.3	14.8	0.10	<0.001	0.17	0.94	1.21	0.15
B3															
B4	7.49	647	93.8	15.7	3.65	18.3	272	53.0	10.3	10.90	0.10	0.017	0.33	11.35	1.18
B5	7.62	825	85.6	21.9	7.51	38.4	267	82.3	24.4	27.50	0.025	<0.005	0.63	28.16	3.53
B6															
B7 P1	7.63	547	96.3	16.5	4.49	16.9	271	55.0	8.2	15.00	<0.001	<0.005	0.33	15.33	0.85
B7 P2	7.60	575	94.7	16.0	5.13	18.3	271	46.3	7.2	14.5	<0.001	0.013	0.41	14.92	0.50
B8 P1	7.60	710	97.4	19.8	3.72	18.2	265	63.7	10.3	12.5	<0.001	<0.005	0.38	12.88	0.28
B8 P2	7.65	598	92.1	18.9	3.74	18.4	261	66.8	10.5	13.0	<0.001	<0.005	0.64	13.64	0.90
B9	7.78	606	92.8	15.0	3.45	17.4	255	90.3	9.9	13.5	<0.001	<0.005	0.75	14.25	4.98

TABLE VII

SUMMARY OF AVAILABLE HISTORICAL TRENDS IN NITRATE CONCENTRATIONS

SAMPLE DESCRIPTION (Well Owner, Number or Location)	ADDRESS OF LOCATION	COMPLETION	1969 (FIELD) (SUMMER)	1985 (HACH) (AUG)	1986 (LAB) (AUG)	1987 (HACH) (AUG)	1987 (LAB) (AUG)	1988 (LAB) (AUG)	1988 (LAB) (OCT)	1989 (HACH) (MARCH)	1989 (LAB) (MARCH)
AREA A											
F. Hosta	12202 Highway 97	In SAGR			10.5	9.5	10.4	8.55			
R. Peel	10815 - 81st Street	In SAGR		ND	11.5	16.0	23.6	19.0			
J.L. Wight	10405 - 81st Street	In SAGR		ND	9.0	12.0	18.0	12.0		>10.0	
J.A. Whitemore	10225 - 81st Street	In SAGR								5.0	
Kettle east of Hwy.	Near centre of Area A									<1.0	
A-1 P1	South end of Area A	In SAGR									7.5
A-1 P2	South end of Area A	In SAGR									9.49
A-2 P1	CPR Right-of-way	In SAGR									
A-3 P1	A. Gaspar Property (Hwy. 97 South)	In SAGR									
AREA BETWEEN AREAS A & B											
A.J. Trudel	9409 - 79th Street	In SAGR			13.0	15.5	26.7	22.0			
E. Slingby	9419 - 79th Street	In SAGR			11.0	15.0	8.94				
Mantles	9417 - 79th Street	In SAGR			5.0	4.5	6.16				
Nundel	9405 - 79th Street	In SAGR			7.0	7.5	9.12				
AREA B											
L. Martins	107th Street	In SAGR			10.0	8.0	12.3	10.2			
Dunont Auto	93rd Street	In SAGR		12.0	13.0	11.0	14.2	7.99			
D. McDermid	6806 Highway 97	In SAGR			6.5	<1.0	.25				
E.J. Lang	2803 - 89th Street	In SAGR		9.0	8.0	6.0	10.7		8.87		
G.R. Kelm	7007 - 103rd Street	In SAGR								2.5	
P. Fodey	8214 - 103rd Street	In SAGR								>10.0	
Site 1 - Hole A	MOE Obs Well 92	In SANDY SILT	.82								
Site 1 - Hole B	MOE Obs Well 93	In SAGR	.54								
Site 2 - Hole A		In SANDY SILT									
Site 2 - Hole B		In SAGR									
Site 3	MOE Obs Well 95	In SANDY SILT	.55								
Site 4 - Hole A	MOE Obs Well 96	In SANDY SILT	2.22	5.0	6.5-9.0			3.12	3.1		
Site 4 - Hole B	MOE Obs Well 97	In SAGR		22.0	ND-2.0			2.39	10.2		
B-1 P2	South end of Peanut L.	In SAND									6.79
B-1 P2	South end of Peanut L.	In SAGR									3.00
B-1 P3	South end of Peanut L.	In SAGR									0.10
B-3 P1	N. end Elks Parking Lot	In SAGR									
B-4 P1	End of 70th Ave. Cul-de-Sac	In SAND									10.90
B-5 P1	West end of 74th Avenue	In SAGR									27.50
B-6 P1	Cul-de-Sac by Police Station	In SAGR									
B-7 P1	By trailer in Orch. on 103rd St.	In SAGR									15.00
B-7 P2	By trailer in Orch. on 103rd St.	In SAGR									14.50
B-8 P1	Pfingstfag Prop near Elks Lodge	In SAGR									12.50
B-8 P2	Pfingstfag Prop near Elks Lodge	In SAGR									13.00
B-9 P1	Behind Kobau Bowling Alley	In SAGR									13.50
Kettle near Hwy. 97	Near Elks Lodge									<1.0	

NOTES: 1. ND = Not Detected
2. SAGR indicates Sand & Gravel

TOWN OF OSOYOOS PRODUCTION WELLS

WELL NO.	DATE	NITRATE + NITRITE (mg-N/L)
1	02/07/73	7.2
	25/01/77	7.4
	10/04/85	6.8
2	25/01/77	8.4
	06/05/85	6.33

From Hodge, Dec. 1985(b)

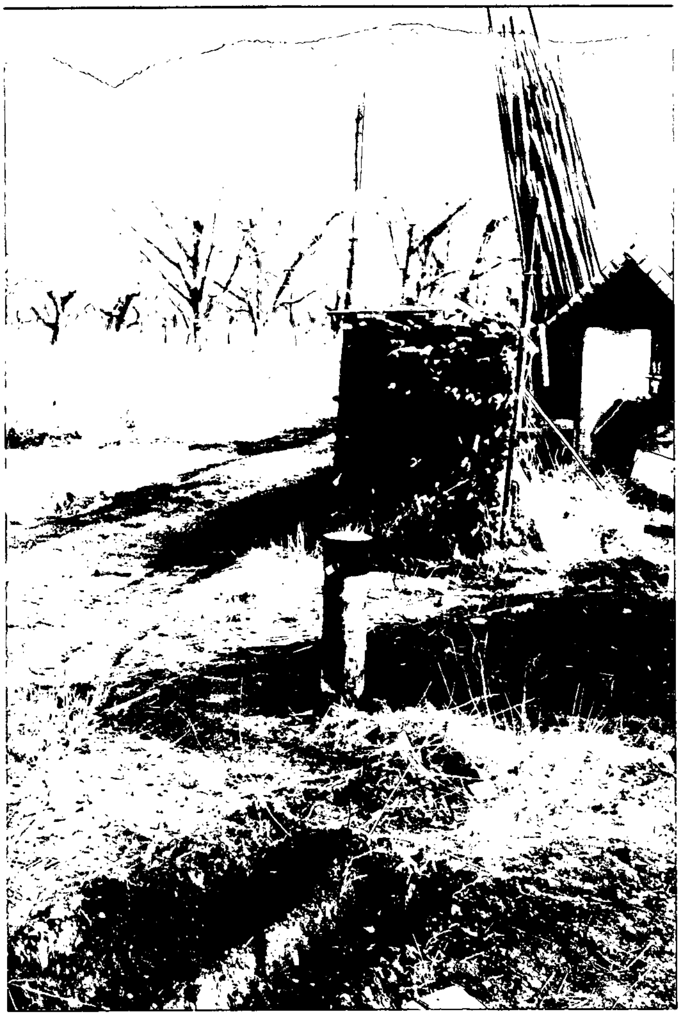


Photo 1. Monitoring Piezometer Installation B-7

Photo 2. Broken ice on kettle near centre of Area A, showing decline in water level since freeze-up.

APPENDIX A

DRILLHOLE LOGS

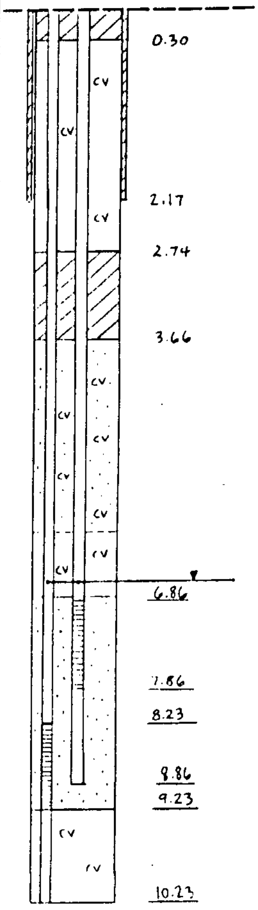
HYDROGEOLOGIC LOG

DRILLHOLE No. **A 1**
Sheet 1 of 1

PROJECT OSOYOOS GROUNDWATER MONITORING PROJECT

Purpose of hole MONITORING
Coordinates:
E
N
Angle from horizontal 90°
Bearing °Azimuth
Type of drilling AIR ROTARY
Rig FUTROS
Drilling fluid AIR

Reference elevation 284 m - asl
Elevation type: Surveyed ☐ Altimeter ☐ From map ☒
Casing stick up 0.88 m-above ground



(1)(2)* Lithology	(2)(3) Completed Construction	During Drilling (2) Depth (m)	During Drilling (2)(4) Water Level (m)	During Drilling (5) Water Flow (Lps)	During Drilling (6) Other	After Drilling (2)(7) Water Level (m)	After Drilling (8) Hydraulic Conductivity Test Type	Hydraulic Conductivity Value (m/s)	Hydraulic Conductivity (2) Depth (m)	Comments
Ground level										
med brn sa-sr SAND and GRAVEL 3.66		G.S. G.S. G.S.								
med brn sa-sr SAND and GRAVEL with some cobbles 9.14		G.S. G.S. G.S. G.S. G.S. G.S.				6.56				
brownish grn sandy SILT, tr fn gravel, tr clay										

2
4
6
8
10

Contractor FIELD DRILLING
Date started 12/3/89
Date finished 12/3/89
Logged by PRM
Checked by
Date

SCALE: Vertical 1: approximate
Horizontal - N.t.s.

*Bracketed numbers refer to notes following the logs

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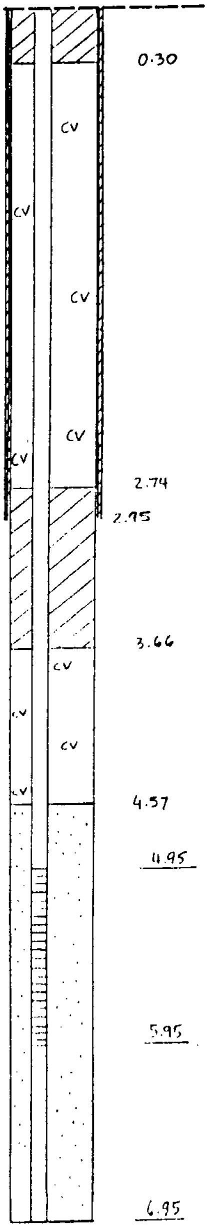
HYDROGEOLOGIC LOG

DRILLHOLE No. **A 2**
Sheet 1 of 1

PROJECT OSOYOOS GROUNDWATER MONITORING PROJECT
Purpose of hole MONITORING
Coordinates:
E
N
Angle from horizontal 90°
Bearing °Azimuth
Type of drilling AIR ROTARY
Rig FUTROS
Drilling fluid AIR
Reference elevation 285 m - asl
Elevation type: Surveyed ☐ Altimeter ☐ From map ☒
Casing stick up 0.69 m - above ground
Job No.

(1)(2)* Lithology	(2)(3) Completed Construction	During Drilling (2) Depth (m)	During Drilling (2)(4) Water Level (m)	During Drilling (5) Water Flow (Lps)	During Drilling (8) Other	After Drilling (2)(7) Water Level (m)	After Drilling (8) Hydraulic Conductivity Test Type	After Drilling Hydraulic Conductivity Value (m/s)	After Drilling Hydraulic Conductivity (2) Depth (m)	Comments
Ground level										
		G.S.								
		G.S.								
med brn sa-sr SAND and GRAVEL		G.S.								
		G.S.								
4.57		G.S.								
med brn sa-sr SAND and GRAVEL with some cobbles		G.S.								
5.95		G.S.								
brownish grn sandy SILT, tr fn gravel, tr clay										

Contractor FIELD DRILLING
Date started 12/3/89
Date finished 12/3/89
Logged by PRM
Checked by
Date
SCALE: Vertical 1: approximate
Horizontal - N.t.s.
*Bracketed numbers refer to notes following the logs

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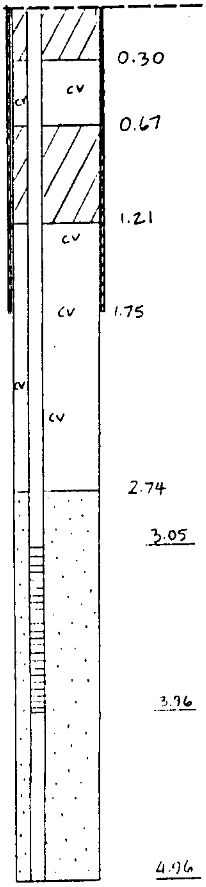
HYDROGEOLOGIC LOG

DRILLHOLE No. **A 3**
Sheet 1 of 1

Job No.

PROJECT OSOYOOS GROUNDWATER MONITORING PROJECT
Purpose of hole MONITORING
Coordinates:
E
N
Angle from horizontal 90°
Bearing °Azimuth
Type of drilling AIR ROTARY
Rig FUTROS
Drilling fluid AIR
Reference elevation 312 m - asl
Elevation type: Surveyed ☐ Altimeter ☐ From map ☒
Casing stick up 0.69 m-above ground

(1)(2)* Lithology	(2)(3) Completed Construction	During Drilling (2) Depth (m)	During Drilling (2)(4) Water Level (m)	During Drilling (5) Water Flow (Lps)	During Drilling (8) Other	After Drilling (2)(7) Water Level (m)	After Drilling (8) Hydraulic Conductivity Test Type	After Drilling (8) Hydraulic Conductivity Value (m/s)	After Drilling (2) Depth (m)	Comments
Ground level med brn sa-sr SAND and GRAVEL gravel coarsening with depth 2.74		G.S. G.S. G.S.								
med brn sa-sr SAND and GRAVEL with some cobbles 3.96		G.S. G.S.								
brownish grn sandy SILT, tr fn gravel, tr clay										

Contractor FIELD DRILLING
Date started 14/3/89
Date finished 14/3/89
Logged by PRM
Checked by
Date
SCALE: Vertical 1: approximate
Horizontal - N.t.s.
* Bracketed numbers refer to notes following the logs

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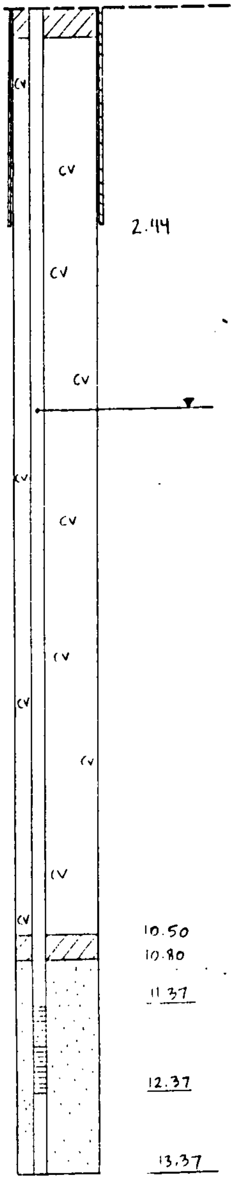
HYDROGEOLOGIC LOG

DRILLHOLE No. **B1a**
Sheet 1 of 1

Job No.

PROJECT OSOYOOS GROUNDWATER MONITORING PROJECT
Purpose of hole MONITORING
Coordinates:
E
N
Angle from horizontal 90°
Bearing °Azimuth
Type of drilling AIR ROTARY
Rig FUTROS
Drilling fluid AIR

Reference elevation 287 m - asl
Elevation type: Surveyed ☐ Altimeter ☐ From map ☒
Casing stick up 0.65 m-above ground



(1)(2)* Lithology	(2)(3) Completed Construction	During Drilling (2) Depth (m)	During Drilling (2)(4) Water Level (m)	During Drilling (5) Water Flow (Lps)	During Drilling (6) Other	After Drilling (2)(7) Water Level (m)	After Drilling (8) Hydraulic Conductivity Test Type	Hydraulic Conductivity Value (m/s)	Hydraulic Conductivity (2) Depth (m)	Comments
Ground level										
dk brn sa-sr SAND and GRAVEL										
1.83		G.S.								
2	2.44	G.S.								
		G.S.								
4		G.S.				4.59				
		G.S.								
6 med brn sa-sr SAND and GRAVEL		G.S.								
		G.S.								
8		G.S.								
		G.S.								
10.06 10		G.S.								
	10.50									
	10.80									
	11.37	G.S.								
12 well washed med-crs SAND	12.37									
		G.S.								
	13.37									
13.71		G.S.								
14		G.S.								
brownish grn sandy SILT, tr fn gravel, tr clay										
16										

Contractor FIELD DRILLING
Date started 9/3/89
Date finished 9/3/89
Logged by PRM
Checked by
Date

SCALE: Vertical 1: approximate
Horizontal - N.t.s.
*Bracketed numbers refer to notes following the logs

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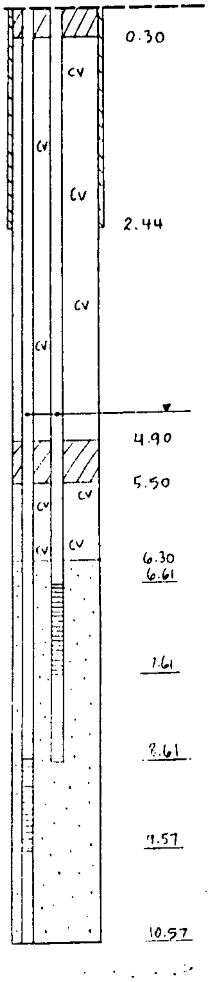
Job No.

HYDROGEOLOGIC LOG

DRILLHOLE No. **B 1b**
Sheet 1 of 1

PROJECT OSOYOOS GROUNDWATER MONITORING PROJECT
Purpose of hole MONITORING
Coordinates:
E
N
Angle from horizontal 90°
Bearing °Azimuth
Type of drilling AIR ROTARY
Rig FUTROS
Drilling fluid AIR
Reference elevation 287 m - asl
Elevation type: Surveyed ☐ Altimeter ☐ From map ☒
Casing stick up 0.57 m - above ground

(1)(2)* Lithology	(2)(3) Completed Construction	During Drilling (2) Depth (m)	During Drilling (2)(4) Water Level (m)	During Drilling (5) Water Flow (Lps)	During Drilling (6) Other	After Drilling (2)(7) Water Level (m)	After Drilling (8) Hydraulic Conductivity Test Type	After Drilling (8) Hydraulic Conductivity Value (m/s)	After Drilling (8) Hydraulic Conductivity (2) Depth (m)	Comments
Ground level										
dk brn med SAND, tr gravel, some										
183										
med brn sa-sr SAND and GRAVEL						4.62				
10.06										
well washed med-crs SAND										
13.71										
brownish grn sandy SILT, tr fn gravel, tr clay										



Contractor FIELD DRILLING
Date started 13/3/89
Date finished 13/3/89
Logged by PRM
Checked by
Date

SCALE: Vertical 1: approximate
Horizontal - N.t.s.
*Bracketed numbers refer to notes following the logs

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HYDROGEOLOGIC LOG

DRILLHOLE No. B 3
Sheet 1 of 1

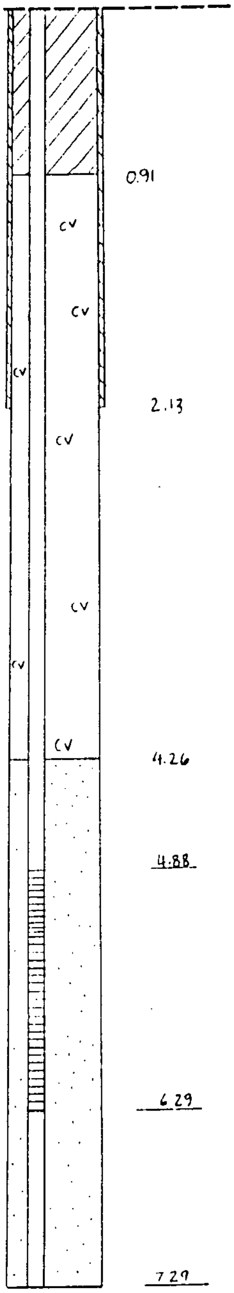
PROJECT OSOYOOS GROUNDWATER MONITORING PROJECT
Purpose of hole MONITORING
Coordinates:
E
N
Angle from horizontal 90°
Bearing °Azimuth
Type of drilling AIR ROTARY
Rig FUTROS
Drilling fluid AIR

Reference elevation 307 m - asl
Elevation type: Surveyed ☐ Altimeter ☐ From map ☒
Casing stick up 0.66 m-above ground

Job No

(1)(2)* Lithology	(2)(3) Completed Construction	During Drilling: (2) Depth (m)	During Drilling: (2)(4) Water Level (m)	During Drilling: (5) Water Flow (Lps)	During Drilling: (6) Other	After Drilling: (2)(7) Water Level (m)	After Drilling: (8) Hydraulic Conductivity: Test Type	After Drilling: (8) Hydraulic Conductivity: Value (m/s)	After Drilling: (8) Hydraulic Conductivity: (2) Depth (m)	Comments
Ground level										
greyish brn sa-sr SAND and GRAVEL 1.83		G.S. G.S.								
greyish brn sr fn-med SAND, tr fn gravel 2.74		G.S								
greyish brn sa-sr SAND and GRAVEL, occasional tr. silt 6.40		G.S. G.S. G.S.								
brownish grn sandy SILT, tr fn gravel, tr clay										

Depth scale: 1, 2, 3, 4, 5, 6, 7



Contractor FIELD DRILLING
Date started 9/3/89
Date finished 10/3/89
Logged by PRM
Checked by
Date

SCALE: Vertical 1: approximate
Horizontal - N.t.s.
*Bracketed numbers refer to notes following the logs

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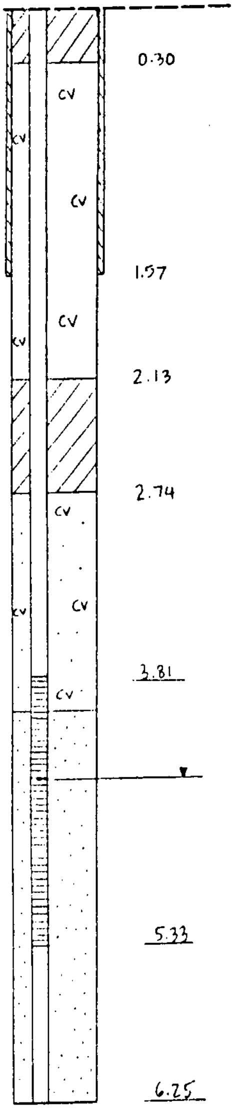
HYDROGEOLOGIC LOG

DRILLHOLE No. **B 4**
Sheet 1 of 1

Job No.

PROJECT OSOYOOS GROUNDWATER MONITORING PROJECT
Purpose of hole MONITORING
Coordinates:
E
N
Angle from horizontal 90°
Bearing °Azimuth
Type of drilling AIR ROTARY
Rig FUTROS
Drilling fluid AIR
Reference elevation 304 m - asl
Elevation type: Surveyed ☐ Altimeter ☐ From map ☒
Casing stick up 0.65 m - above ground

(1)(2)* Lithology	(2)(3) Completed Construction	During Drilling: (2) Depth (m)	During Drilling: (2)(4) Water Level (m)	During Drilling: (5) Water Flow (Lps)	During Drilling: (6) Other	After Drilling: (2)(7) Water Level (m)	After Drilling: (8) Hydraulic Conductivity: Test Type	After Drilling: (8) Hydraulic Conductivity: Value (m/s)	After Drilling: (8) Hydraulic Conductivity: (2) Depth (m)	Comments
Ground level		G.S. G.S. G.S. G.S. G.S. G.S.				4.40				
1										
2 med brn sa-sr SAND and GRAVEL										
3										
4										
4.57										
5 moe. well washed med SAND, tr. gravel										
5.50										
6										
7 brownish grn sandy SILT, tr fn gravel, tr clay										

Contractor FIELD DRILLING
Date started 10/3/89
Date finished 10/3/89
Logged by PRM
Checked by
Date

SCALE: Vertical 1: approximate
Horizontal - N.t.s.
*Bracketed numbers refer to notes following the logs

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HYDROGEOLOGIC LOG

DRILLHOLE No. **B 5**
Sheet 1 of 1

Job No.

PROJECT OSOYOOS GROUNDWATER MONITORING PROJECT

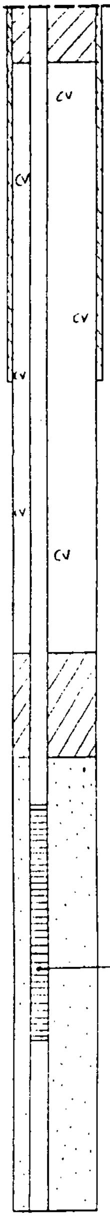
Purpose of hole MONITORING

Coordinates:
E
N

Angle from horizontal 90°
Bearing °Azimuth

Type of drilling AIR ROTARY
Rig FUTROS
Drilling fluid AIR

Reference elevation 305 m - asl
Elevation type: Surveyed ☐ Altimeter ☐ From map ☒
Casing stick up 0.93 m-above ground



	(1)(2)* Lithology	(2)(3) Completed Construction	During Drilling				After Drilling				Comments
			(2) Depth (m)	(2)(4) Water Level (m)	(5) Water Flow (Lps)	(6) Other	(2)(7) Water Level (m)	(8) Hydraulic Conductivity			
								Test Type	Value (m/s)	(2) Depth (m)	
	Ground level										
	0.30	0.30									
			G.S.								
1											
			G.S.								
2		2.25									
	lt-med brn sa SAND and GRAVEL (v. hard zone at 1.7m - possibly cemented)		G.S.								
3											
		3.66	G.S.								
4											
		4.27									
		4.57	G.S.								
5											
			G.S.				5.49				
		5.89									
6	6.10		G.S								
		6.89									
7	brownish grn sandy SILT, tr fn gravel, tr clay										
8											

Contractor FIELD DRILLING
Date started 10/3/89
Date finished 10/3/89

Logged by PRM
Checked by
Date

SCALE: Vertical 1: approximate
Horizontal - N.t.s.

*Bracketed numbers refer to notes following the logs

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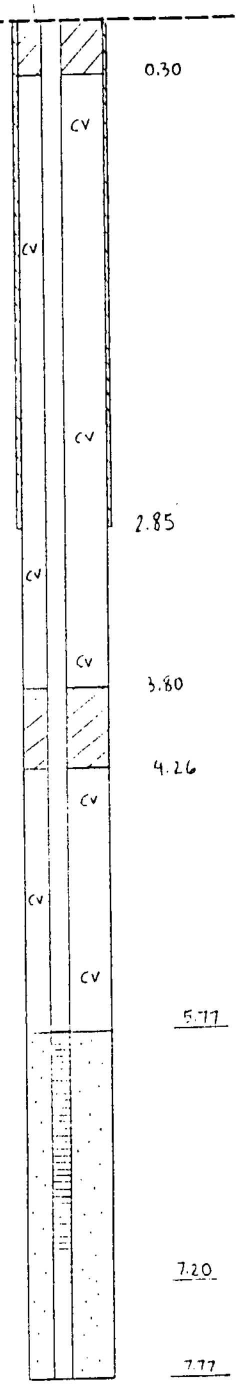
HYDROGEOLOGIC LOG

DRILLHOLE No. B 6
Sheet 1 of 1

Job No

PROJECT OSOYOOS GROUNDWATER MONITORING PROJECT
Purpose of hole MONITORING
Coordinates:
E
N
Angle from horizontal 90⁰
Bearing °Azimuth
Type of drilling AIR ROTARY
Rig FUTROS
Drilling fluid AIR
Reference elevation 305 m - asl
Elevation type: Surveyed ☐ Altimeter ☐ From map ☒
Casing stick up 0.89 m-above ground

(1)(2)* Lithology	(2)(3) Completed Construction	During Drilling (2) Depth (m)	During Drilling (2)(4) Water Level (m)	During Drilling (5) Water Flow (Lps)	During Drilling (8) Other	After Drilling (2)(7) Water Level (m)	After Drilling (8) Hydraulic Conductivity Test Type	After Drilling (8) Hydraulic Conductivity Value (m/s)	After Drilling (8) Hydraulic Conductivity (2) Depth (m)	Comments
Ground level										
med brn sa-sr fine-med SAND		G.S. G.S								
3.05										
med brn sr SAND and GRAVEL (cobbles being ground below 4.5m)		G.S. G.S. G.S.								
7.00		G.S.								
brownish grey sand SILT, tr fn gravel, tr. clay										



Depth scale: 1, 2, 3, 4, 5, 6, 7

Contractor FIELD DRILLING
Date started 10/3/89
Date finished 11/3/89
Logged by PRM
Checked by
Date

SCALE: Vertical 1: approximate
Horizontal - N.t.s.
*Bracketed numbers refer to notes following the logs

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HYDROGEOLOGIC LOG

DRILLHOLE No. **B 7**
Sheet 1 of 1

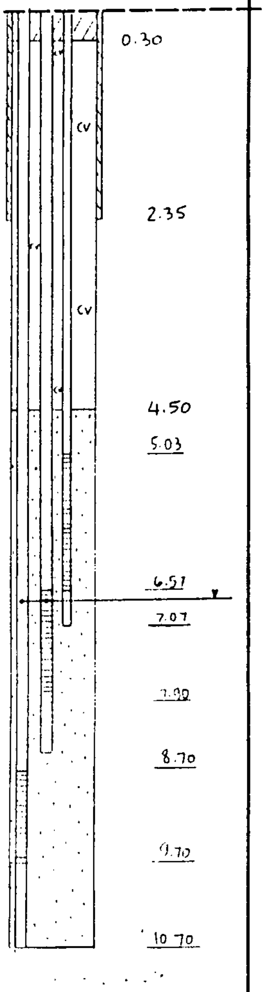
PROJECT OSOYOOS GROUNDWATER MONITORING PROJECT
Purpose of hole MONITORING
Coordinates:
E
N
Angle from horizontal 90°
Bearing °Azimuth
Type of drilling AIR ROTARY
Rig FUTROS
Drilling fluid AIR

Reference elevation 304 m - asl
Elevation type: Surveyed ☐ Altimeter ☐ From map ☒
Casing stick up 0.70 m-above ground

Job No.

(1)(2)* Lithology	(2)(3) Completed Construction	During Drilling (2) Depth (m)	During Drilling (2)(4) Water Level (m)	During Drilling (5) Water Flow (Lps)	During Drilling (6) Other	After Drilling (2)(7) Water Level (m)	After Drilling (8) Hydraulic Conductivity Test Type	Hydraulic Conductivity Value (m/s)	Hydraulic Conductivity (2) Depth (m)	Comments

Ground level



Lithology (depth scale 2, 4, 6, 8, 10):

med brn sa-sr
SAND and GRAVEL
occasional coarse gravel
layers

8.23

med brn sa-sr
SAND and crse
GRAVEL

9.90

brownish grey sandy
SILT, tr fn gravel,
tr clay

During Drilling – Depth (m):
G.S.
G.S.
G.S.
G.S.
G.S.
G.S.
G.S.
G.S.
G.S.
G.S.
G.S.

After Drilling – Water Level (m): 6.74

Contractor FIELD DRILLING
Date started 11/3/89
Date finished 11/3/89
Logged by PRM
Checked by
Date

SCALE: Vertical 1: approximate
Horizontal - N.t.s.
*Bracketed numbers refer to notes following the logs

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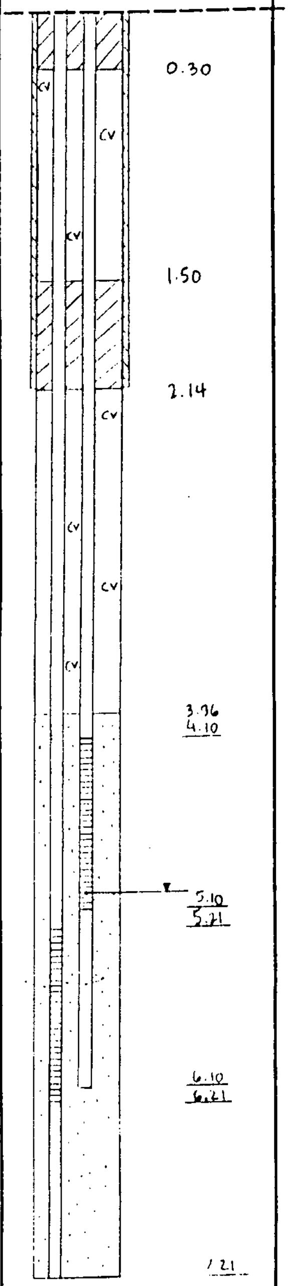
HYDROGEOLOGIC LOG

DRILLHOLE No. B8
Sheet 1 of 1

Job No.

PROJECT OSOYOOS GROUNDWATER MONITORING PROJECT
Purpose of hole MONITORING
Coordinates:
E
N
Angle from horizontal 90°
Bearing °Azimuth
Type of drilling AIR ROTARY
Rig FUTROS
Drilling fluid AIR
Reference elevation 304 m - asl
Elevation type: Surveyed ☐ Altimeter ☐ From map ☒
Casing stick up 0.95 m-above ground

(1)(2)* Lithology	(2)(3) Completed Construction	During Drilling				After Drilling				Comments
		(2) Depth (m)	(2)(4) Water Level (m)	(5) Water Flow (Lps)	(6) Other	(2)(7) Water Level (m)	(8) Hydraulic Conductivity: Test Type	Value (m/s)	(2) Depth (m)	
Ground level										
		G.S.								
		G.S.								
		G.S.								
med brn sa-sr SAND and GRAVEL										
		G.S.								
		G.S.								
						5.03				
		G.S.								
6.40		G.S.								
brownish grey sand SILT, tr fn gravel. tr clay										

Contractor FIELD DRILLING
Date started 13/3/89
Date finished 13/3/89
Logged by PRM
Checked by
Date
SCALE: Vertical 1: approximate
Horizontal - N.t.s.
*Bracketed numbers refer to notes following the logs

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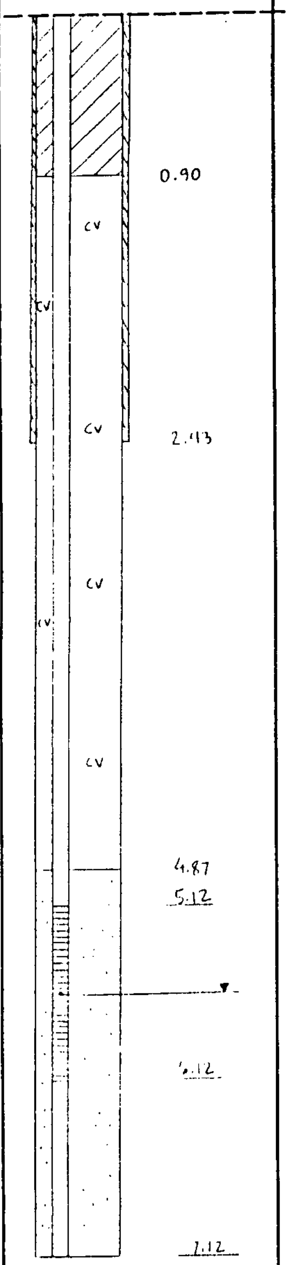
VANCOUVER CALGARY

HYDROGEOLOGIC LOG

DRILLHOLE No. **B 9**
Sheet 1 of 1

PROJECT OSOYOOS GROUNDWATER MONITORING PROJECT
Purpose of hole MONITORING
Coordinates:
E
N
Angle from horizontal 90°
Bearing °Azimuth
Type of drilling AIR ROTARY
Rig FUTROS
Drilling fluid AIR
Reference elevation 305 m - asl
Elevation type: Surveyed ☐ Altimeter ☐ From map ☒
Casing stick up 0.62 m-above ground
Job No.

(1)(2)* Lithology	(2)(3) Completed Construction	During Drilling (2) Depth (m)	During Drilling (2)(4) Water Level (m)	During Drilling (5) Water Flow (Lps)	During Drilling (6) Other	After Drilling (2)(7) Water Level (m)	After Drilling (8) Hydraulic Conductivity Test Type	Hydraulic Conductivity Value (m/s)	Hydraulic Conductivity (2) Depth (m)	Comments
Ground level										
med brn sa-sr SAND and GRAVEL well washed below 6.40m		G.S. G.S. G.S. G.S G.S. G.S. G.S.				5.63				
6.71										
brownish grey sand SILT, tr fn gravel, tr clay										



Contractor FIELD DRILLING
Date started 13/3/89
Date finished 14/3/89
Logged by PRM
Checked by
Date

SCALE: Vertical 1: approximate
Horizontal - N.t.s

*Bracketed numbers refer to notes following the logs

PITEAU & ASSOCIATES
GEOTECHNICAL CONSULTANTS
VANCOUVER CALGARY

APPENDIX B

LABORATORY RESULTS

CHEMICAL ANALYSIS REPORT

ASL

Date: May 1, 1989

File No. 7413A

Report On: Water Samples Dated March 16, 1989

Report To: Piteau & Associates Ltd.
408 - 100 South Park Royal
West Vancouver, B. C.
V7T 1A5

DATE OF SUBMISSION:

March 17, 1989

SAMPLE IDENTIFICATION

Labelled as noted in RESULTS section.

METHODOLOGY

Analysed in accordance with "Standard Methods for the Examination of Water and Wastewater" published by the American Public Health Association, 1985.

RESULTS OF ANALYSIS

Results are presented in the table(s) attached.

ASL ANALYTICAL SERVICE LABORATORIES LTD.

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		A-1 P#1 Mar 16/89	A-1 P#2 Mar 16/89	B-1 P#1 Mar 16/89	B-1 P#2 Mar 16/89
Physical Tests					
pH		7.72	7.69	7.63	7.61
Conductivity		638.	640.	591.	505.
Dissolved Solids		468.	469.	439.	418.
Anions and Nutrients					
Alkalinity	CaCO3	272.	280.	263.	232.
Sulphate	SO4	49.1	45.9	33.2	45.1
Chloride	Cl	11.4	11.1	10.0	13.0
Silicate	SiO2	22.5	23.5	22.0	21.0
D-Phosphorous	P	0.024	0.030	0.010	0.020
T-Phosphorous	P	0.13	1.12	0.088	0.12
Nitrate	N	7.50	9.49	6.79	3.00
Nitrite	N	<0.001	0.010	0.010	<0.001
Ammonia	N	<0.005	<0.005	<0.005	<0.005
Organic Nitrogen	N	0.20	0.34	0.25	0.24
Tot. Kjeldahl	N	0.20	0.34	0.25	0.24
Total Nitrogen	N	7.70	9.84	7.05	3.24
Total Metals					
Aluminium	T Al	2.21	12.9	0.82	1.68
Arsenic	T As	0.0020	0.0057	0.0011	0.0011
Barium	T Ba	0.058	0.20	0.054	0.037
Boron	T B	<0.10	<0.10	0.15	0.11
Cadmium	T Cd	<0.0002	<0.0002	<0.0002	<0.0002
Cobalt	T Co	0.002	0.009	0.001	0.002
Chromium	T Cr	0.008	0.034	0.003	0.004
Copper	T Cu	0.006	0.020	0.005	0.010
Iron	T Fe	3.16	20.4	1.27	2.35
Lead	T Pb	0.009	0.021	<0.001	0.002
Manganese	T Mn	0.088	0.42	0.068	0.18
Molybdenum	T Mo	0.008	0.006	0.004	0.003
Nickel	T Ni	0.004	0.017	0.003	0.006
Sodium	T Na	20.1	22.5	18.7	16.3
Potassium	T K	5.62	14.7	5.58	4.74
Vanadium	T V	<0.050	0.062	<0.050	<0.050
Zinc	T Zn	0.014	0.071	<0.005	0.008
Dissolved Metals					
Aluminium	D Al	0.016	0.036	0.022	0.012
Arsenic	D As	0.0015	0.0015	0.0011	0.0007
Barium	D Ba	0.041	0.046	0.042	0.017
Boron	D B	<0.10	<0.10	0.15	<0.10
Cadmium	D Cd	<0.0002	<0.0002	<0.0002	<0.0002
Cobalt	D Co	<0.001	<0.001	<0.001	<0.001
Chromium	D Cr	0.002	0.002	<0.001	<0.001
Copper	D Cu	0.001	<0.001	0.003	0.003
Iron	D Fe	<0.015	<0.015	<0.015	<0.015
Lead	D Pb	<0.001	<0.001	<0.001	<0.001
Manganese	D Mn	0.007	0.019	0.036	0.009
Molybdenum	D Mo	0.008	0.006	0.004	0.003
Nickel	D Ni	0.001	0.001	<0.001	<0.001
Vanadium	D V	<0.050	<0.050	<0.050	<0.050
Zinc	D Zn	<0.005	0.007	<0.005	<0.005
Calcium	D Ca	73.6	72.9	82.7	74.8
Magnesium	D Mg	28.5	29.7	17.5	14.8
Potassium	D K	4.27	4.20	4.46	3.40
Sodium	D Na	19.3	17.8	18.5	15.3

< = Less than   T = Total   D = Dissolved

Results are expressed as milligrams per litre except for pH and Conductivity (μmhos/cm)

ASL

RESULTS OF ANALYSIS

		B-1 P#3 Mar 16/89	B-4 Mar 16/89	B-5 Mar 16/89	B-~~6~~7 P#1 Mar 16/89
Physical Tests					
pH		7.77	7.49	7,62	7.63
Conductivity		471.	647.	825.	547.
Dissolved Solids		393.	497.	557.	488.
Anions and Nutrients					
Alkalinity	CaCO3	219.	272.	267.	271.
Sulphate	SO4	46.3	53.0	82.3	55.0
Chloride	Cl	14.8	10.3	24.4	8.2
Silicate	SiO2	20.3	25.5	25.0	25.0
D-Phosphorous	P	0.040	0.034	0.088	0.21
T-Phosphorous	P	0.15	1.18	3.53	0.85
Nitrate	N	0.10	10.9	27.5	15.0
Nitrite	N	<0.001	0.10	0.025	<0.001
Ammonia	N	0.17	0.017	<0.005	<0.005
Organic Nitrogen		0.77	0.29	0.63	0.33
Tot. Kjeldahl	N	0.94	0.31	0.63	0.33
Total Nitrogen	N	1.21	11.3	28.2	15.3
Total Metals					
Aluminium	T Al	1.79	10.1	40.3	15.3
Arsenic	T As	0.0011	0.0042	0.0045	0.0043
Barium	T Ba	0.056	0.51	0.43	0.16
Boron	T B	0.14	0.11	0.29	0.17
Cadmium	T Cd	<0.0002	0.0018	0.0004	0.0010
Cobalt	T Co	0.002	0.010	0.017	0.006
Chromium	T Cr	0.004	0.024	0.10	0.016
Copper	T Cu	0.010	0.084	0.087	0.019
Iron	T Fe	2.61	14.3	53.7	8.37
Lead	T Pb	0.005	0.016	0.026	0.008
Manganese	T Mn	0.085	5.78	1.18	0.23
Molybdenum	T Mo	0.003	0.022	0.013	0.005
Nickel	T Ni	0.003	0.045	0.053	0.009
Sodium	T Na	17.2	20.8	41.6	19.0
Potassium	T K	6.58	7.79	15.0	7.77
Vanadium	T V	<0.050	<0.050	0.11	<0.050
Zinc	T Zn	0.011	0.071	0.15	0.033
Dissolved Metals					
Aluminium	D Al	0.013	0.015	0.035	0.014
Arsenic	D As	0.0011	0.0014	0.0023	0.0039
Barium	D Ba	0.034	0.036	0.048	0.093
Boron	D B	<0.10	<0.10	0.010	0.14
Cadmium	D Cd	<0.0002	<0.0002	<0.0002	0.0003
Cobalt	D Co	<0.001	<0.001	<0.001	<0.001
Chromium	D Cr	<0.001	<0.001	<0.001	<0.001
Copper	D Cu	0.002	0.003	0.004	0.006
Iron	D Fe	<0.015	<0.015	<0.015	<0.015
Lead	D Pb	<0.001	<0.001	<0.001	<0.001
Manganese	D Mn	0.022	<0.005	0.026	<0.005
Molybdenum	D Mo	0.003	0.010	0.010	0.004
Nickel	D Ni	<0.001	<0.001	0.001	<0.001
Vanadium	D V	<0.050	<0.050	<0.050	<0.050
Zinc	D Zn	0.005	<0.005	<0.005	<0.005
Calcium	D Ca	58.3	93.8	85.6	96.3
Magnesium	D Mg	21.3	15.7	21.9	16.5
Potassium	D K	5.46	3.65	7.51	4.49
Sodium	D Na	16.6	18.3	38.4	16.9

< = Less than T = Total D = Dissolved

Results are expressed as milligrams per litre except for pH and Conductivity (μmhos/cm)

RESULTS OF ANALYSIS

		B-~~8~~7 P#2 Mar 16/89	B-8 P#1 Mar 16/89	B-8 P#2 Mar 16/89	B-9 Mar 16/89
Physical Tests					
pH		7.60	7.60	7.65	7.78
Conductivity		575.	710.	598.	606.
Dissolved Solids		489.	508.	496.	515.
Anions and Nutrients					
Alkalinity	CaCO3	271.	265.	261.	255.
Sulphate	SO4	46.3	63.7	66.8	90.3
Chloride	Cl	7.2	10.3	10.5	9.9
Silicate	SiO2	26.0	25.5	24.8	21.5
D-Phosphorous	P	0.21	0.058	0.076	0.072
T-Phosphorous	P	0.50	0.28	0.90	4.98
Nitrate	N	14.5	12.5	13.0	13.5
Nitrite	N	<0.001	<0.001	<0.001	<0.001
Ammonia	N	0.013	<0.005	<0.005	<0.005
Organic Nitrogen	N	0.40	0.38	0.54	0.75
Tot. Kjeldahl	N	0.41	0.38	0.54	0.75
Total Nitrogen	N	14.9	12.9	13.5	14.3
Total Metals					
Aluminium	T Al	3.72	3.05	11.9	45.5
Arsenic	T As	0.0055	0.0033	0.0038	0.011
Barium	T Ba	0.085	0.10	0.24	0.54
Boron	T B	0.23	0.16	<0.10	0.13
Cadmium	T Cd	<0.0002	<0.0002	0.0003	0.0005
Cobalt	T Co	0.003	0.002	0.007	0.017
Chromium	T Cr	0.010	0.010	0.027	0.14
Copper	T Cu	0.016	0.029	0.092	0.095
Iron	T Fe	4.66	4.09	12.3	67.7
Lead	T Pb	0.007	0.004	0.010	0.029
Manganese	T Mn	0.15	0.12	0.72	1.03
Molybdenum	T Mo	0.005	0.015	0.020	0.004
Nickel	T Ni	0.007	0.020	0.018	0.073
Sodium	T Na	18.7	19.9	21.9	21.6
Potassium	T K	6.69	4.75	8.92	20.2
Vanadium	T V	<0.050	<0.050	<0.050	0.11
Zinc	T Zn	0.026	0.023	0.047	0.22
Dissolved Metals					
Aluminium	D Al	0.018	0.013	0.035	0.031
Arsenic	D As	0.0040	0.0019	0.0020	0.0023
Barium	D Ba	0.056	0.071	0.078	0.065
Boron	D B	0.16	0.14	<0.10	<0.10
Cadmium	D Cd	<0.0002	<0.0002	<0.0002	<0.0002
Cobalt	D Co	<0.001	<0.001	<0.001	<0.001
Chromium	D Cr	0.001	0.001	0.001	0.001
Copper	D Cu	0.005	0.013	0.004	0.004
Iron	D Fe	<0.015	0.018	0.018	<0.015
Lead	D Pb	<0.01	<0.001	<0.001	<0.001
Manganese	D Mn	0.009	0.017	0.011	0.018
Molybdenum	D Mo	0.004	0.012	0.012	0.004
Nickel	D Ni	<0.001	0.004	0.003	0.006
Vanadiu;m	D V	<0.050	<0.050	<0.050	<0.050
Zinc	D Zn	<0.005	<0.005	<0.005	0.007
Calcium	D Ca	94.7	97.4	92.1	92.8
Magnesium	D Mg	16.0	19.8	18.9	15.0
Potassium	D K	5.13	3.72	3.74	3.45
Sodium	D Na	18.3	18.2	18.4	15.4

< = Less than T = Total D = Dissolved
Results are expressed as milligrams per litre except for pH and Conductivity (µmhos/cm)

APPENDIX C

SUMMARY OF WELL INFORMATION AVAILABLE FOR OSOYOOS AREA

DIGITIZED COORDINATES (m)		Z	X	Y	BCGS MAP AREA	OLD WELL NO.	NEW WELL NO.	AREA	OWNER	DATE CONSTRUCTED (DMY)	COLLAR ELEV	WELL DEPTH		DRILLED/ DUG (?) (DR/DU)	WELL DIAM (in)	WELL YIELD	DEPTH TO WATER		DEPTH TO CLAY		IN USE ? (Y/N)	COMMENT	HARD	FE	PH	DESCRIPTION
X	Y											(FT)	(m)				(FT)	(m)	(FT)	(m)						
2182.65	181.33	1	9	9		1																				
2160.87	329.96			9		2																				
2139.23	466.51			9		3																				
1922	464.08			9		4																				
1646.53	271.9	1	9	9	082E.003.2.3.2	69	41		VILLAGE	Sep-80	330m	100	30.48	MUD ROT	8	COMM	46	14.02	83	25.30	Y	SCRN 49-59'				0-18 SAGR ,18-32 CLAY,32-54 F SAND/SILT, 54-64 SAGR,64-79 SILT,79-83 SAGR,83-100 CLAY
2415.71	208.08			9		7																				
2676.43	279.4			9		32																				
3008.15	118.15			9		9																				
2992.79	411.69			9		8																				
2758.66	481.49			9		29																				
2773	638.56			9		30																				
2553.56	833.26			9		10		B																		
2524.23	937.54			9		11		B																		
2459.5	969			9		12		B																		
2362.01	1052.4			9		46		B																		
2274.13	995.09			9		16		B																		
2123.11	828.44			9		48																				
2238.56	938.37			9		5		B																		
3226.72	720.09			9		6		B																		
3217.33	840.68			9		51		B																		
3163.32	992.97			9		19		B																		
3145.2	1173.82			9		20		B																		
3001.01	1115.88			9		53		B																		
2961.41	1059.11			9		52		B																		
2841.13	1021.55			9		47		B																		
2740.97	984.22			9		22		B																		
2744.4	1036.56			9		21		B																		
2691.3	1108.39			9		49		B																		
2514.15	1118.48			9		31		B																		
2214.48	1292.16			9		6		B																		
2053.52	1294.38			9		65		B																		
2080.24	1423.43			9		64		B																		
2120.02	1464.11			9		14		B																		
1822.24	1468.83			9		15		B																		
1845.66	1533.46			9		23		B																		
2588.34	1320.48			9		55		B																		
2426.3	1419.26			9		13		B																		
2480.73	1588.85			9		33		B																		
2630.66	1493.96			9		45		B																		
2611.04	1449.49			9		17		B																		
2679.02	1486.46			9		42		B																		
2812.81	1395.42			9		28		B																		
2861.44	1363.77			9		26		B																		
2934.35	1320.33			9		27		B																		
3002.92	1305			9		25		B																		
3096.03	1253.74			9		24		B																		
3214.35	27.91			3?		24																				
4142.05	179.11			10		16																				
4030.04	121.53			10		15																				
3885.22	119.91			10		14																				
3789.17	74.58			10		13																				
3760.29	138.63			10		2																				
3736.65	94.11			10		22																				
3696.46	89.64			10		4																				

DIGITIZED COORDINATES (m) X	Y	Z	X	Y	BCGS MAP AREA	OLD WELL NO.	NEW WELL NO.	AREA	OWNER	DATE CONSTRUCTED (DMY)	COLLAR ELEV	WELL DEPTH (FT)	(m)	DRILLED/ DUG (?) (DR/DU)	WELL DIAM (in)	WELL YIELD	DEPTH TO WATER (FT)	(m)	DEPTH TO CLAY (FT)	(m)	IN USE ? (Y/N)	COMMENT	HARD	FE	PH	DESCRIPTION
3667.54	157.71			10		23																				
3627.4	149.22			10		3																				
3374.61	448.15			10		5																				
3305.41	519.79			10		6																				
3283.81	652.33			10		7		B																		
3303.25	712.89			10		8		B																		
3262.61	748.65			10		18		B																		
3310.3	801.49			10		9		B																		
918.11	2806.56	1	9	17	082E.003.2.3.1	4	1		DRIVE-INN	Aug-68	151?	80	24.38	DR	21?	.5GPM	50	15.24	30	9.14	Y?					0-30 SAND , 30-94 CLAY
873.23	2862.39	1	9	17	082E.003.2.3.1	5	2		McKENZIE	Oct-76	115?	275	83.82	AIR ROT	6	12GPM	61.8	18.85	24	7.32	Y					0-6 SAND, 6-24 SAGR, 24-24.5 CLAY TILL, 24.5-275 BEDROCK
870.31	4202.16	1	9	17	082E.003.2.3.3	2	11	A	ISAEK	Oct-64		12	3.66	DU		DOM	6-8				Y					GRAV
987.76	4493.17	1	9	20	082E.003.2.3.3	20	9	A	BESLER	Jan-65	151?	32	9.75	DU	36	DOM	27	8.23	28	8.53	Y					0-2 SOIL, 2-28 GRAV, 28-32 CLAY
648.94	4569.84	1	9	20	082E.003.2.3.3	5	4	A	BUCKSHAW	Jan-54		27	8.23	DU/DRIV		DOM	23-24				Y	SANDPOINT 17'				SAGR
456.52	4507.34	1	9	20	082E.003.2.3.3	6	18	A	HOSTA	Jan-61		40	12.19	DU		DOM	35	10.67	36	10.97	Y					0-36 GRAV , 36-40 CLAY
260	4810.92	1	9	20	082E.003.2.3.3	7	5		SAND	Jan-51		35	10.67	DU		DOM	33-35		30	9.14	Y					0-30 GRAV , 30-35 BLUE CLAY
764.72	5009.69	1	9	20	082E.003.2.3.3	11	7	A	STANLEY	Jan-57		17	5.18	DRIVEN		DOM	0-16				Y					SAGR
815.89	5110.85	1	9	20	082E.003.2.3.3	4	3	A	LYONS	Jan-50		15	4.57	DU		DOM	5-14.5		15	4.57	Y					GRAV, BLU E CLAY @ BOTTOM
231.41	5208.92	1	9	20	082E.003.2.3.3	13	8		McCRAE	Jan-54		15	4.57	DRIVEN		DOM	10	3.05			Y					F-C GRAV
1949.07	2359.43	1	9	16	082E.003.2.3.1	1	3	B	FALKENBERG	Jan-59		29	8.84	DU/DRIV		DOM	29	8.84			Y					M GRAVEL
1983.66	2504.66	1	9	16	082E.003.2.3.1	2	4	B	FALKENBERG	Jan-55		26	7.92	DU		DOM	16-24				Y					M GRAVEL
1768.65	2663.19	1	9	16	082E.003.2.3.1	3	5	B	TOTH	Oct-64		21	6.40	DU		IRR	18	5.49	21	6.40	Y	IN SUMMER				SAGR,BLUE CLAY @ BOTTOM
1751.74	2735.42	1	9	16	082E.003.2.3.1	4	6	B	FODEY	Jan-57		18	5.49	DU		DOM	8-14				Y					SAGR
2208.94	2507.18	1	9	16	082E.003.2.3.2	5	1	B	SULZ -MOTEL	Jan-50		22	6.71	DU	36	MOTEL	16-21				N	ON S.O.L.I.D.				SAGR
2404.08	2686.39	1	9	16	082E.003.2.3.2	6	2	B	HOLZ, F.	Oct-64		25-30		DU		DOM					Y					SAGR
2000.13	2830.74	1	9	16	082E.003.2.3.2	7	7	B	FESSER	Jan-57		20	6.10	DRIVEN		DOM	16	4.88			N	ON S.O.L.I.D.				SANDY GRA V, LAYER OF CLAY
2007.09	2927.38	1	9	16	082E.003.2.3.2	8	8	B	DRY	Jan-46		18	5.49	DRIVEN		DOM	14	4.27			N	ON S.O.L.I.D.				SANDY GRA VEL
2081.82	3081.11	1	9	16	082E.003.2.3.2	9	37	B	DUMONT	Jan-54		16	4.88	DRIVEN		DOM	?		16	4.88	Y	HACH 23/8/85				SAGR, HAR D ON BOTTOM
2162.09	3098.1	1	9	16	082E.003.2.3.2	10	38	B	DUMONT	Jan-60		18	5.49	DRIVEN		SHOP	>14		18	5.49	Y	HACH 23/8/85				SAGR, SIL T BELOW 18'
2125.3	3149.99	1	9	16	082E.003.2.3.2	11	39	B	DUMONT	Jan-40		24	7.32	DRIVEN		DOM	20	6.10			Y					SAGR
2048.51	3181.32	1	9	16	082E.003.2.3.2	12	3	B	TEXACO	Oct-64		22	6.71	DRIVEN		DOM	18	5.49			N	ON S.O.L.I.D.				SAGR
2288.51	2946.62	1	9	16	082E.003.2.3.2	13	40	B	NYEHOLT	Jan-61		30	9.14	DU		DOM	20-29		30	9.14	N	UNDER ROAD	136	NIL	7.6	CLN GRAV, HARDPAN @ BOTTOM
2502.99	2836.37	1	9	16	082E.003.2.3.2	14	4	B	AVALON HOTEL	Jan-49		31	9.45	DU		MOTEL	18-29		31	9.45	N	ON S.O.L.I.D.				0-3 SOIL, 3-31 F SAND, GR-BL SILT/HARD ON BOTTOM
2411.33	3116.98	1	9	16	082E.003.2.3.2	15	5	B	POLICE STATION	Jan-58		23	7.01	DU		DOM	23	7.01	23	7.01	N	ON S.O.L.I.D.				0-22 SAND , 22-23 BLUE SILT (@ BOTTOM)
2353.61	3241.06	1	9	16	082E.003.2.3.2	16	6	B	PLAZA PROPERTY	Jan-61		25	7.62	DU		DOM	17-22				N	ON S.O.L.I.D.				M SAND
2042.64	3346.22	1	9	16	082E.003.2.3.2	17	17	B	VACANT	Jan-58		28	8.53	DRIVEN		DOM	24	7.32			N?					SAGR
2158.63	3407.87	1	9	16	082E.003.2.3.2	36	11	B	PORTUGUESE	Apr-65		24	7.32	DU	48	DOM/GA	20	6.10			N					1-22 CLN SAGR,22-24 CLN SAGR + ROCK
2218.66	3436.7	1	9	16	082E.003.2.3.2	18	8	B	SNYDER	Jan-63		30	9.14	DRIVEN		DOM	15-20				N					SAGR
2286.95	3445.51	1	9	16	082E.003.2.3.2	19	9	B	MOTZ ?	Oct-64		12	3.66	DU		DOM/GA	9	2.74			N	ON S.O.L.I.D.				SAGR
2351.27	3450.26	1	9	16	082E.003.2.3.2	21	10	B	APPELT	Oct-64		20	6.10	DRIVEN		DOM	5-15				N	ON S.O.L.I.D.				SANDY GRA VEL
1970.3	2979.27	1	9	16	082E.003.2.3.1	24	10	B	MEIER	Jan-64		22	6.71	DU		DOM	10-19				N	ON S.O.L.I.D.				SAND & F GRAV
2355.71	2693.9	1	9	16	082E.003.2.3.2	44	16	B	JENSEN	Jan-66	152?	24	7.32	DU		DOM	20	6.10	24	7.32	N	ON S.O.L.I.D.				CLN GRAV, CLAY @ BOTTOM
2937.82	3887.33			16		33		B													N					
3020.37	3341.06			16		20		B													N					
2984.2	2978.55	1	9	16	082E.003.2.3.2	41	13	B	KUN	Jan-66	152?	28	8.53	DU/DR	6	DOM	?				N	ON S.O.L.I.D.				NONE
3026.31	2810.03	1	9	16	082E.003.2.3.2	42	14	B	HEBIS	Jan-66	152?	16	4.88	DU		DOM	10	3.05			N	ON S.O.L.I.D.				CLN SAGR
3158.89	2827.61	1	9	16	082E.003.2.3.2	43	15	B	SAUNDERS	Jan-66	152?	15	4.57	DU		DOM	DRY				N	ON S.O.L.I.D.				CLN GRAV
2064.58	1745.13	1	9	9	082E.003.2.3.2	35	18	B	KELLERMAN	Jan-50		20-25		DU		DOM	15-20				Y	CONC RINGS				F SAGR
2116.87	1745.72	1	9	9	082E.003.2.3.2	56	28	B	GROUNDWATER	Aug-69	999.55	33	10.06	DR	2	CITY	7.54	2.30	33	10.06	Y	SCRN 28-33				0-33 SAGR , 33-50 CLAY
2165.06	1754.3	1	9	9	082E.003.2.3.2	55	27	B	GROUNDWATER	Aug-69	1000.19	50	15.24	DR	2	CITY	8.53	2.60	33	10.06	Y	SCRN 40-45				0-33 SAGR , 33-50 CLAY
2192.5	1818.98	1	9	9	082E.003.2.3.2	58	30	B	GROUNDWATER	Sep-69	1005.55	50	15.24	DR	2	CITY	9.47	2.89	20	6.10	Y	SCRN41.5-46.5				0-20 SAGR , 20-50 CLAY
2140.24	1814.38	1	9	9	082E.003.2.3.2	57	29	B	GROUNDWATER	Sep-69	1004.65	18.	5.64	DR	2	CITY	9.98	3.04	20	6.10	Y	SCRN 15-20				0-20 SAGR , 20-50 CLAY
2099.84	1830.02	1	9	9	082E.003.2.3.2	36	19	B	PFINGSTAGG	Oct-64		15	4.57	DU		DOM	7-15				Y					F GRAV

DIGITIZED COORDINATES (m)		Z	X	Y	BCGS MAP AREA	OLD WELL NO.	NEW WELL NO.	AREA	OWNER	DATE CONSTRUCTED (DMY)	COLLAR ELEV	WELL DEPTH		DRILLED/ DUG (?) (DR/DU)	WELL DIAM (in)	WELL YIELD	DEPTH TO WATER		DEPTH TO CLAY		IN USE ? (Y/N)	COMMENT	HARD	FE	PH	DESCRIPTION
X	Y											(FT)	(m)				(FT)	(m)	(FT)	(m)						
2689.69	1611.3			9		50		B																		
2744.35	1760.78	1	9	9	082E.003.2.3.2	68	36	B	VILLAGE	May-79	115?	65	19.81	CABLE TL	8	CITY	0.00		34.5	10.52	Y					0-4 SOIL, 4-22 F SAND, 22-34.5 F SAGR, 34.5-65 CLAY
2759.67	1829.35	1	9	9	082E.003.2.3.2	44	25	B	VILLAGE	Mar-65	.5?	34	10.36	DU	48	1000GP	7	2.13	37	11.28	Y	RECOND 1985				0-20 SAGR, 20-37 COBL GRAV, 37 CLAY
		1	9	9	082E.003.2.3.2	43	24	B	VILLAGE	Jan-57		29	8.84	CLAM SH	36	350GPM	4	1.22			Y	10 SND POINTS				GRAV
		1	9	9	082E.003.2.3.2	41	23	B	VILLAGE	May-64	152?	31	9.45	CLAM SH		500GPM	14	4.27	28	8.53	Y					0-28 SAGR, 28-31 CLAY
		1	9	16	082E.003.2.3.2	40	12	B	BUCKSHAW	Jan-66	152?	29.	8.99	DU		DOM	24	7.32	29.5	8.99	N	ON S.O.L.I.D.				CLN GRAV, CLAY @ BOTTOM
2882.81	1971.55	1	9	9	082E.003.2.3.2	67	35	B	VILLAGE	Sep-78	114?	42	12.80	AIR DR	6	CITY	14	4.27	25	7.62	Y?					0-12 C SAND, 12-25 SAGR, 25-42 CLAY
2945.78	2096.98	1	9	9	082E.003.2.3.2	40	22	B	VILLAGE	Jun-63	152?	28	8.53	DU	48	750GPM	10	3.05	28	8.53	Y	CONC RINGS				0-6 SOIL, 6-28 SAGR, 28 CLAY
3006.08	2101.68	1	9	9	082E.003.2.3.2	39	21	B	VILLAGE	Jan-59	151?	30	9.14	DU	48	350GPM	13	3.96	30	9.14	Y	CONC RINGS				0-5 SOIL, 5-15 GRAV, 15-18 CLAY, 18-30 SAGR,30 CLAY
3126.76	2103.03			9		45		B																		
2965.31	2149.51			9		41		B																		
2868.53	2168.54	1	9	9	082E.003.2.3.2	54	26	B	SCHOOL	Jan-64	152?	28	8.53	DU		?	19	5.79			Y?					0-6 SOIL, 6-28 SAGR
1415.87	2908.7	1	9	16	082E.003.2.3.1	23	9	B	PENDERGRAFT	Jan-64	152?	32	9.75	DU		DOM	22-30		30	9.14	N	ON S.O.L.I.D.				0-30 SAGR,30-32 BLUE CLAY
1731.94	3427.23	1	9	16	082E.003.2.3.1	25	11	B	BACHMAN	Jan-45		35	10.67	DU		2 DOM	33	10.06	35?		N	ON S.O.L.I.D	204	NIL	7.7	GRAV,HARD SILT IN GRAV
1560.36	3658.67	1	9	16	082E.003.2.3.3	26	13		PLEVA	Jan-61		18	5.49	DU		DOM	12	3.66	15	4.57	N	ON S.O.L.I.D.				0-15 SAGR, 15-18 BLUE CLAY
1344.86	3861.46			16		39																				
1300.34	3885.1	1	9	16	082E.003.2.3.3	28	14		STEFANIDES	Oct-64		14-16		DU		DOM	5-6				Y					C SAGR
1210.98	3960.55			16		34																				
1157.78	4040.42			16		35		A																		
2160.13	3633.19	1	9	20		20		A																		
1152.07	4551.33	1	9	21	082E.003.2.3.3	2	1	A	PORTUGUESE	Jan-47		12	3.66	DU		DOM	1-11.5		12	3.66	Y					GRAV, BLUE CLAY @ BOTTOM
1771.05	4606.54	1	9	21	082E.003.2.3.3	5	17	A	WIGHT	Jun-70	151?	10	3.05	DU	36	25GPM	5	1.52			Y	SUMMER	HACH 8/85			GRAV
1811.09	4623.08	1	9	21	082E.003.2.3.3	1	15	A	WIGHT	Jan-45		10	3.05	DU		DOM	8	2.44			Y					GRAV
1795.45	4582.67	1	9	21		7		A																		
1957.72	4463.78	1	9	21	082E.003.2.3.3	3	2	A	SPARKS	Jun-65	151?	10	3.05	DU	36	DOM	6	1.83			Y	HACH 8/85				GRAV
2129.29	4232.34			16		47																				
2156.95	4276.91			16		22																				
2768.02	4319.36			16		31																				
2816.61	4292.34			16		38																				
2837.44	4228.2			16		46																				
2821.76	4191.81			16		45																				
2850.77	4115.69			16		37																				
2814.93	4083.1			16		27																				
2883.14	4099.96			16		49																				
2935.16	4124.68			16		48																				
2971.05	4153.24			16		39																				
3107.61	4174.89			16		29																				
2945.48	4281.71			16		30																				
3321.65	2664.47			15		17		B																		
663.63	5414.93			20		1		A																		
590.4	5486.53			20		2																				
634.34	5515.19			20		3																				
412.5	5565.01			20		21																				
2170.27	2007.84	1	9	9	082E.003.2.3.2	59	31	B	GROUNDWATER	Sep-69	1010.72	48	14.63	DR	2	CITY	19.8	6.04	19	5.79	Y	SCRN 36.5-41.5				0-19 SAGR, 19-48 CLAY
2258.86	2000.78	1	9	9	082E.003.2.3.2	62	33	B	CORBETT	Jun-69	151?	28	8.53	DR	36	20GPM	22	6.71			Y	CONC RINGS				SAGR
2000.18	2106.52	1	9	9	082E.003.2.3.1	60	12	B	GROUNDWATER	Sep-64	1006.29	35	10.67	DR	?		12.8	3.93	17	5.18	Y	SCRN 28-33'				0-3.5 SIL SAND,3.5-17 SAGR,17-35 CLAY
2064.59	2103.22	1	9	9	082E.003.2.3.2	61	32	B	GROUNDWATER	Sep-69	1004.92	20	6.10	DR	2	CITY	12.1	3.71			Y	SCRN 11-16'				REF SITE 4 HOLE A
2310.62	2049.64	1	9	9	082E.003.2.3.2	63	34	B	FODOR	Jun-69	151?	26	7.92	DR	36	40GPM	18	5.49			Y	CONC RINGS				SAGR
2336.96	1852.79	1	9	9	082E.003.2.3.2	37	20	B	TOWNROW	Jan-61		30	9.14	DU		DOM	18-26		20	6.10	Y					0-20 M GRAV, 20-30 BLUE CLAY
2322.89	1671.58	1	9	9	082E.003.2.3.2	34	17	B	MILLER	Oct-64		16	4.88	DU		DOM	12-13				Y				>7	SAGR
2625.33	1610.58			9		18		B																		

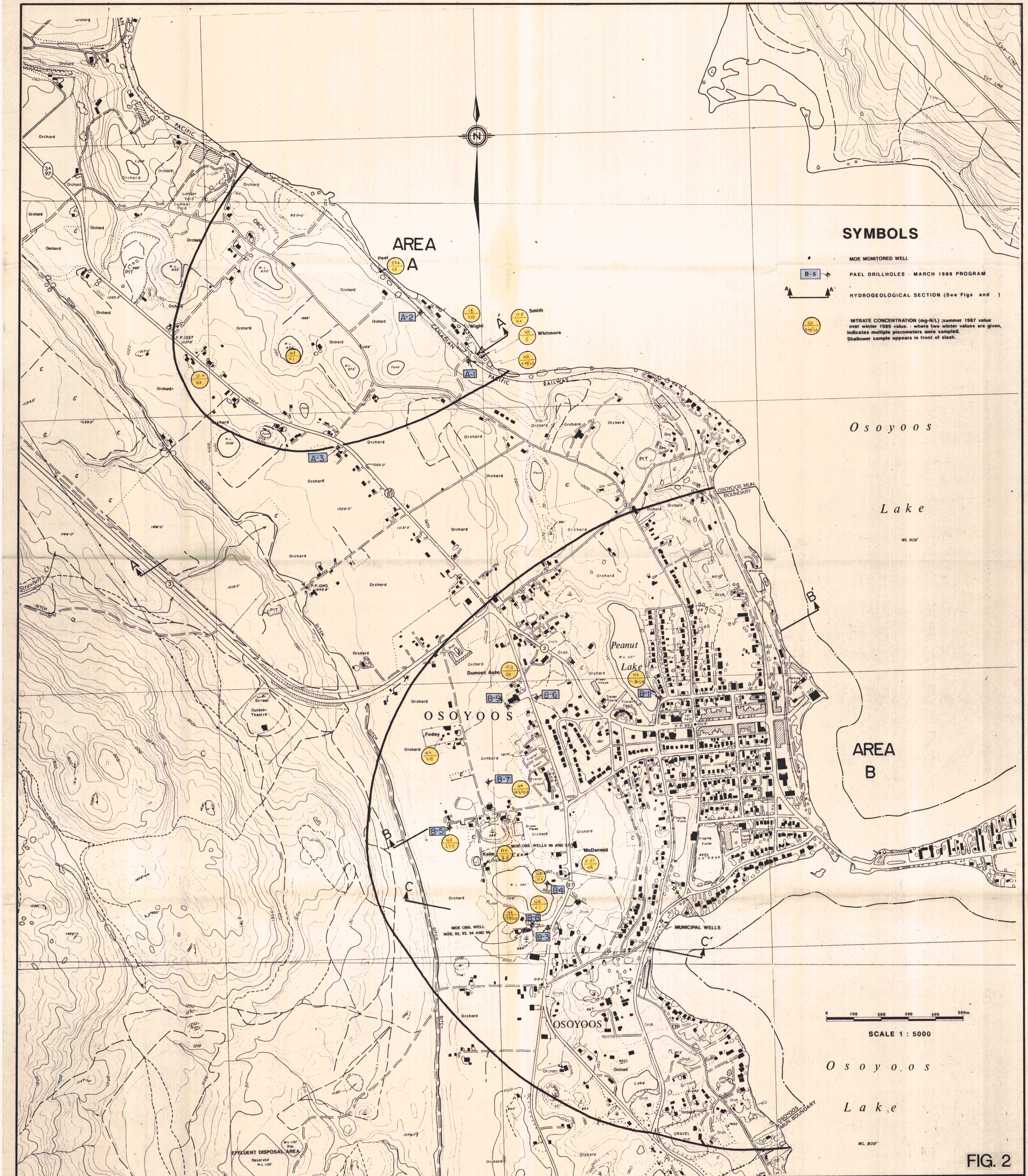


FIG. 2

MINISTRY OF ENVIRONMENT
GROUNDWATER SECTION

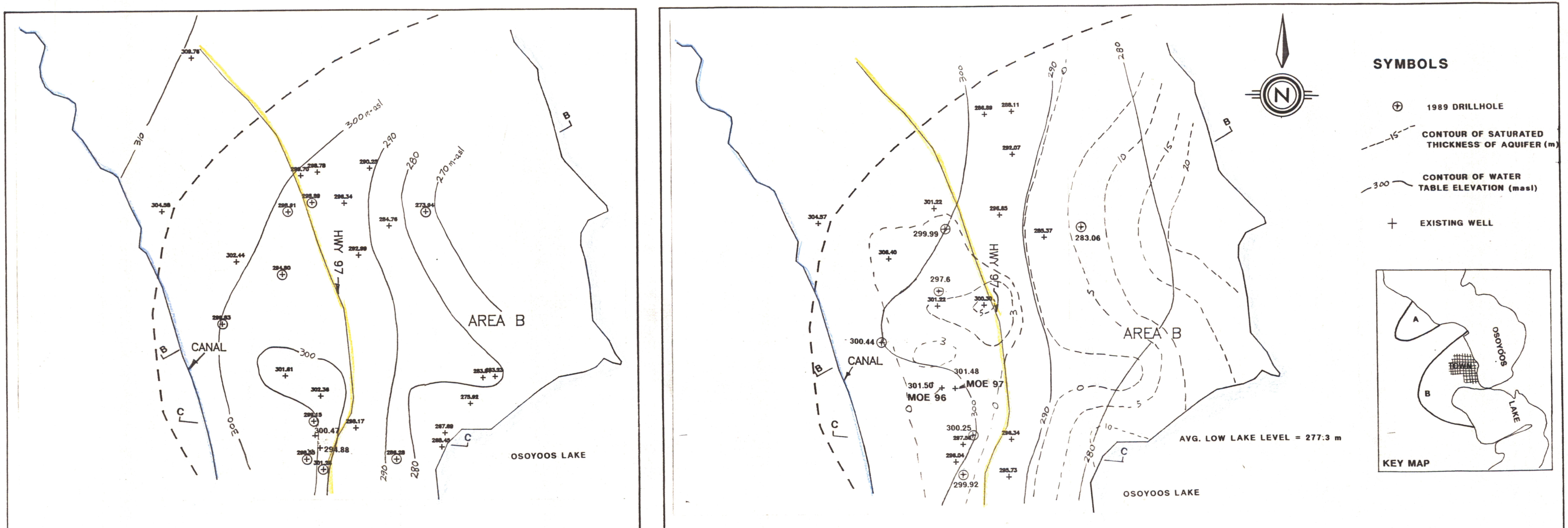
PITEAU ASSOCIATES
GEOTECHNICAL CONSULTANTS
VANCOUVER CALGARY

OSOYOOS GROUNDWATER
MONITORING PROGRAM
OSOYOOS, B.C.

PLAN OF STUDY AREA

PRM APR 89

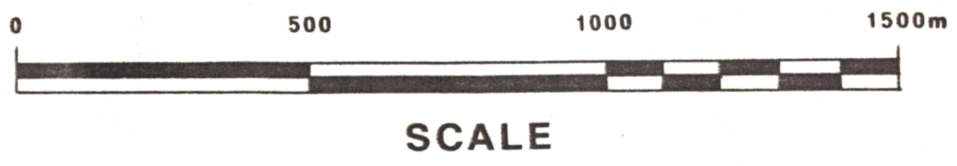
JOB NUMBER



a) ELEVATION OF TOP OF SANDY SILT UNIT IN AREA B

b) ELEVATION OF WATER TABLE AND SATURATED THICKNESS OF AQUIFER IN AREA B

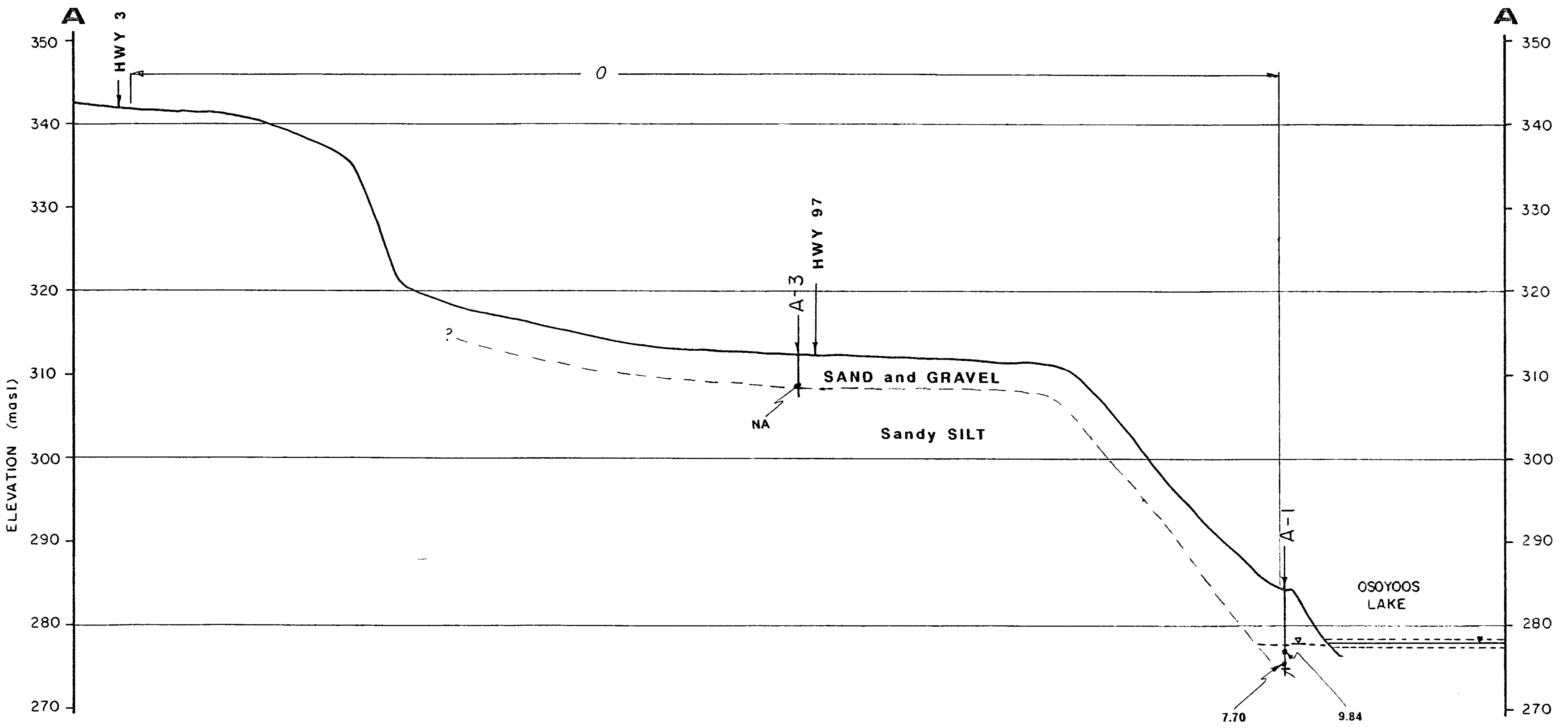
FIG.6



NOTE THE WATER LEVELS USED IN THIS INTERPRETATION WERE MEASURED DURING THE WINTER

MINISTRY OF ENVIRONMENT GROUNDWATER SECTION	PITEAU ASSOCIATES GEOTECHNICAL CONSULTANTS VANCOUVER CALGARY		
OSOYOOS GROUNDWATER MONITORING PROGRAM OSOYOOS, B.C.	ELEVATION OF TOP OF SANDY SILT, WATER TABLE, AND SATURATED THICKNESS OF AQUIFER IN AREA B	BY: PRM APPROVED:	DATE: APR 1989 DWG:

JOB NUMBER________



Symbols:

▽ WATER LEVEL (March 1989)

- - - - CONTACT BETWEEN LITHOLOGIC UNIT

LAKE LEVELS
(Averages for High, Medium and Low)

0 APPROXIMATE EXTENT OF ORCHARDS

Notes:

1. SEE FIGURE 2 FOR LOCATION OF SECTION
2. SECTIONS BASED ON 1989 DRILLHOLES AND ON REVIEW OF PREVIOUSLY CONSTRUCTED WELLS
3. WINTER 1989 NITRATE LEVELS AS mg/L SHOWN. NA INDICATES NOT AVAILABLE

FIG.7

MINISTRY OF ENVIRONMENT
GROUNDWATER SECTION

PITEAU ASSOCIATES
GEOTECHNICAL CONSULTANTS
VANCOUVER CALGARY

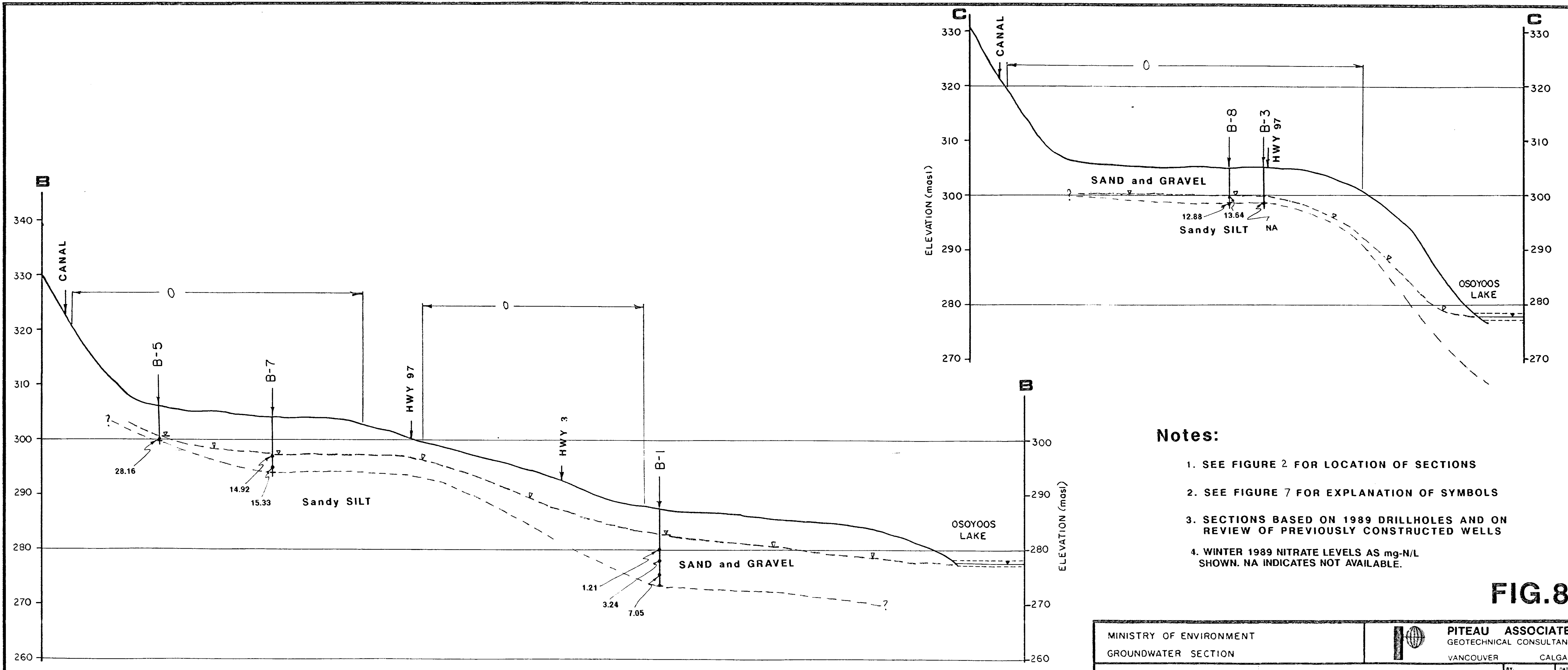
OSOYOOS GROUNDWATER
MONITORING PROGRAM
OSOYOOS B.C.

HYDROGEOLOGICAL SECTION A-A'

AREA A

BY PRM
DATE MAR 89
APPROVED
DWG

JOB NUMBER



Notes:

1. SEE FIGURE 2 FOR LOCATION OF SECTIONS
2. SEE FIGURE 7 FOR EXPLANATION OF SYMBOLS
3. SECTIONS BASED ON 1989 DRILLHOLES AND ON REVIEW OF PREVIOUSLY CONSTRUCTED WELLS
4. WINTER 1989 NITRATE LEVELS AS mg-N/L SHOWN. NA INDICATES NOT AVAILABLE.

FIG.8

MINISTRY OF ENVIRONMENT
GROUNDWATER SECTION

PITEAU ASSOCIATES
GEOTECHNICAL CONSULTANTS
VANCOUVER CALGARY

OSOYOOS GROUNDWATER
MONITORING PROGRAM
OSOYOOS, B.C.

HYDROGEOLOGICAL SECTIONS
B-B' AND C-C' AREA B

BY PRM
DATE MAR 89
APPROVED
DWG