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# CITY OF WILLIAMS LAKE

# HYDROGEOLOGICAL ASSESSMENT

# FOR WELL PROTECTION PLAN

# SCOUT ISLAND WELL FIELD

# WILLIAMS LAKE, B.C.

Prepared for

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Prepared by

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# 1. INTRODUCTION

## 1.1 BACKGROUND

The City of Williams Lake (the City) has developed the Scout Island Well Field to withdraw water from an aquifer which underlies the central portion of the Williams Lake Valley. A new well (PW-5) has recently been constructed on the north shore of Williams Lake, opposite Scout Island. This well has been commissioned following approval under the Environmental Assessment Process (EAP). One of the requirements of the EAP approval was that a Well Protection Plan be implemented to preserve the quality of the groundwater supply.

## 1.2 WELL PROTECTION PLAN SCOPE

Well protection plans are developed by a committee which has representation from the various stakeholders involved in the aquifer, the government agencies that regulate industrial or resource activity in the aquifer recharge area, and the industries active in the interpreted well capture zone. Technical information is provided, so that decisions on what measures should be incorporated in the plan can be made in an informed and quantitative manner.

Technical information can be provided at any time in the process. However, it is often helpful to have knowledge of the recharge area and likely issues that the plan must address at the outset of the planning process, as this will assist in determining the representation required on the Well Protection Planning Committee.

Piteau Associates Engineering Ltd. has completed an initial assessment to define the extent of the well capture zone. The Well Protection Area has been characterized and potential contamination concerns have been identified. The results of the initial assessment, and recommendations for the Well Protection Plan, are presented in this report.

# 2. DATA COMPILATION

Data were compiled on water wells, geology, hydrogeology, water quality and land use in the area, as follows.

## 2.1 WELL LOGS

Locations for all wells in the study area were extracted from the Ministry of Water, Land and Air Protection (MWLAP) database using a search routine, and plotted on a plan of the study area. Well tag numbers were posted beside each well location. Logs for selected wells, required for interpreting hydrogeological sections and aquifer extent, were then downloaded from the MWLAP database.

Logs for three test wells and one production well were also reported for the PW-5 development program (EBA, 2000 and 2001).

Well logs reported in the geotechnical assessment of the Canadian Tire site were reviewed (Terra Engineering Ltd., 1997).

## 2.2 SURFICIAL GEOLOGY

Surficial geology data for the area was interpreted on four sections through the valley. The sections were based on well logs and a surficial geology map (Tipper, 1971). Interpretations were checked against aquifer maps prepared by MWLAP.

## 2.3 GROUNDWATER LEVELS

A near continuous record of groundwater level data is provided by the Provincial Observation Well #88, located on Scout Island. The record reported herein extends from October 1971 to the end of 2001.

In addition to the water level monitoring data from Observation Well #88, some water level information was reported on the well logs obtained from MWLAP files. Information on water levels measured in the 2000 series test wells was also reported by EBA (2000 and 2001).

## 2.4 GROUNDWATER AND LAKE WATER CHEMISTRY

Water quality data have been compiled by the City for the four production wells on Scout Island, for the period 1971 to 2002. These data provide a record of water quality changes that have occurred since PW-1 was first commissioned.

In addition to well water quality, the chemistry of Williams Lake was assessed in the mid 1980's. Data from this study provide a good indication of lake water quality (McKean et al, 1986).

## 2.5 MAPPING

Topographical plans and zoning maps of the area were obtained, at 1:10,000 scale. The City also provided ortho airphotographs that covered the Well Protection Area.

## 2.6 CONTAMINATED SITES

The contaminated site registry was queried to obtain a list of contaminated sites within the study area. Files for sites that were expected to fall within the Well Protection Area were then reviewed in the MWLAP offices by Mr. Matt Pye, during his site visit of March 6, 2003. Basic information on the expected contaminants and the site status was obtained from the files.

# 3. PHYSIOGRAPHY

## 3.1 SETTING

Williams Lake is a 7 km long by 1,200m wide lake located on the south side of the City (Fig. 1). The Lake is situated in a steep walled valley that is generally oriented in a northwesterly-southeasterly direction, but which trends east-west where the lake is located. The Scout Island Well Field is located on a small peninsula near the outlet of Williams Lake (Fig. 2).

The Williams Lake River flows from the western end of the Lake to the Fraser River, located approximately 11 km to the west. The San Jose River flows into the eastern end of the Lake, and drains the area between Williams Lake and Lac la Hache. Including all the tributaries, the San Jose River drains an area extending south almost to 100 Mile House, and southeast almost to Forest Grove (see Fig. 1).

The elevation of Williams Lake is approximately 567m. Valley walls on the north and south side of the Lake rise at slopes of between about 10 and 40% to plateaus at an elevation of about 940m (Fig. 2).

## 3.2 CLIMATE

Williams Lake is in the North Interior climate zone. Average annual precipitation recorded at the nearest climate station (Williams Lake Airport, elev. 940m) is only 426m (Environment Canada, 1991).

Precipitation occurs over the entire year, but spring is the driest season (average April precipitation is 21.5mm), and summer and autumn are the wettest (average July precipitation is 51.4mm). The mean number of days without precipitation is 131, distributed evenly throughout the year.

The average annual air temperature is 4.1°C, and average monthly values range from –8.7°C in January up to 15.4°C in July.

## 3.3 GEOLOGY

### 3.3.1 Bedrock Geology

Bedrock in the Williams Lake area has been mapped by Tipper (1959). Bedrock which underlies the area consists of volcanic and metamorphosed sedimentary rocks, primarily argillite, greenstone, chert, limestone and basalt.

Some major faults are known to be present in the area, and the San Jose/Williams Lake Valley has likely been eroded along one of these fault structures. A bedrock channel has also been eroded beneath the Missioner Creek Valley, which runs into the Williams Lake Valley downstream of the lake, but this channel is at a higher elevation than the base of the Williams Lake River Valley (Aquaterre Consultants Inc., September 1986).

### 3.3.2 Surficial Geology

The slopes and upland plateau areas in the study area are mantled by a blanket of glacial deposits that range in composition from sand and gravel to clay, and range in thickness up to 60m deep. These glacial deposits are generally not thick enough and/or permeable enough to be considered as good aquifers in the area, and most of the wells which have been drilled outside the valley bottom have been completed in bedrock. However, some localized areas of deep surficial sediments have been identified in the Dog Creek Road area.

Based on well logs compiled for the area, a bedrock channel is interpreted to underlie the Williams Lake Valley (Figs. 3, 4 and 5). This channel has been infilled by a sequence of ice-contact sand and gravel sediments

Shallow sediments beneath the valley bottom area are typically fine grained. Silty sand, which may be a lacustrine deposit, was encountered near surface in Wells PW-2 and PW-3, and both lacustrine sediments and glacial till were encountered in the upper 10 to 20m of Wells PW-1 and PW-4. In the golf course well located 2 km downstream, a 16m layer of dense till was encountered immediately below ground surface. A 10m thick silt layer capped the underlying sand and gravel in TW00-03. Clayey and silty sediments were noted in the logs for all water wells located in the industrial valley bottom area downstream of Scout Island (Figs. 4 and 5), and hard silty till deposits were noted beneath the Canadian Tire site on the northeast corner of Highway 20 and South Lakeside Drive (Terra, 1997). Based on this information, a nominal 15 to 20m thick layer of very silty or clayey sediments is interpreted to be present over the valley bottom area at least as far downstream as the golf course well (Figs. 3 and 5).

A section interpreted across the lake about 1.5 km east of Scout Island shows very thick deposits of clay (nominally 80m) confining a thin sand and gravel layer deposited on bedrock (Fig. 5). A surficial clay layer is also interpreted on the north side of the lake, but is only about 10 to 15m thick. Similar fine grained deposits were noted above sand and gravel in well logs located further east, along both the north and south shores of the lake.

Beneath Scout Island, permeable glacio-fluvial sand and gravel sediments are present below a depth of 15 to 20m, to a depth in excess of 80m. The log for Well PW-4 indicates a clay layer at a depth of 79m (260 ft), but whether this is an interbed or the base of the aquifer is not known. Permeable sand and gravel sediments are known to extend to a depth of at least 52m (172 ft) at the golf course well site (Figs. 3 and 5). Sand and gravel were also noted to a depth of 77m (250 ft) in TW00-03, located across the river from the golf course well (EBA, 2000). The extent of these permeable sediments downstream of the golf course and upstream of Scout Island is not known, but they are definitely confined to a bedrock channel in the bottom of the valley, as shown on Figs. 4 and 5. Similar sand and gravel deposits have been noted in a bedrock channel in the Missioner Creek Valley, but the total thickness of these deposits was less than about 10m (Aquaterre Consultants Inc., September 1986).

### 3.3.3 Regional Hydrogeology

The main aquifers in the study area are comprised of the ice-contact sediments that have infilled the base on the bedrock channels in the area, and fractured zones within the bedrock. The ice-contact sand and gravel aquifer which underlies Scout Island and extends upstream and downstream for an unknown distance is the most prolific aquifer in the area. A smaller sand and gravel aquifer that has been identified beneath the Missioner Creek Valley is not as productive as the one beneath Williams Lake (Aquaterre Consultants Inc., September 1986).

The till and silty interbeds which have been noted in the upper portion of the ice contact sediment sequence, and the silty sand lacustrine deposits which were noted in the logs for production Wells PW-2 and PW-3, are considered to form an aquitard overlying the aquifer. This aquitard will partially restrict downward seepage of surface water from Williams Lake and local rivers and creeks into the aquifer. Soft sediment accumulations on the bottom of Williams Lake will augment this confining layer where they are present.

The many wells that have been completed in bedrock in the Missioner Creek Valley (Aquaterre Consultants Inc., February 1986), Southside (Aquaterre Consultants Inc., February 1986; well logs from MWLAP files), Dog Creek Road (Aquaterre Consultants Inc., February 1986) and Esler (Piteau Associates Engineering Ltd., 1988) indicate that the bedrock in the area is a consistent aquifer, but is generally capable of supplying only small to moderate yields (0.1 to 2 L/s). However, some wells with yields in the 12 L/s range have been drilled, indicating some permeable fault zones within the rock mass can be considered as productive aquifers.

# 4. AQUIFER CHARACTERIZATION

## 4.1 PHYSICAL DESCRIPTION

The aquifer which underlies Scout Island was created by glacial scouring of a channel in the bedrock, and subsequent infilling of this channel with a sequence of permeable ice-contact sand and gravel that is in excess of 60m thick. The permeable sediments were covered with a cap of till and/or silty fine sand and silt deposited when the water level in the lake rose to its present level, or possibly higher. The geometry of the fine sediments and till over coarse, permeable sediments has created a confined or semi-confined aquifer, which is typical of aquifers found in many of the glaciated valleys in British Columbia.

The channel aquifer is estimated to be on the order of 400 to 800m wide at the outlet of Williams Lake, and is estimated to range between 1 and 1.5km wide beneath the lake (Fig. 3). The extent of the aquifer in the downstream direction is not known, but it does extend at least 1.5 km to the golf course well (Fig. 5), and likely extends all the way to the Fraser River, although possibly on a reduced scale. It is expected to become unconfined at some point below the golf course.

The aquifer extent in the upstream direction can only be inferred. Productive irrigation wells have been drilled at 141 Mile House in the San Jose Valley (see Fig. 1) and at 150 Mile House in the Borland Creek Valley (Aqua Installations Ltd., pers. comm.), indicating that the main channel aquifer or smaller tributary aquifers extend up both of these valleys. Holes drilled on Candycane I.R. No. 1, where the San Jose River flows into Williams Lake, have typically encountered silty sediments and very low yields to depths in the order of 100m (Piteau, 2003). One recent well encountered an artesian aquifer, but it is not likely to be of great extent (Dave Tiplady, pers. comm.)

Based on the above information, the aquifer developed by the Scout Island Well Field is interpreted to pinch out beneath Williams Lake. Some groundwater flow will enter the aquifer from east of the Lake, as flow within silty sediments and permeable interbeds, but this would represent a relatively small quantity of the aquifer water balance.

## 4.2 HISTORY OF DEVELOPMENT

Initial exploration for a groundwater supply for the City was conducted in 1967-1968 by the Water Investigations Branch of the B.C. Ministry of the Environment. The exploration program delineated the channel aquifer beneath the outlet of Williams Lake, and the first production well was constructed in 1968 and commissioned a short time later. A second well was constructed under the direction of Dayton & Knight Ltd. in 1971, and was put into service later that year. In 1976, a third production well was constructed which was put into continuous service a few years later.

By the early 1980's, the capacity of the Scout Island Well Field was almost fully utilized during peak demand periods, and additional capacity was needed. Aquaterre Consultants Inc. was commissioned to supervise the construction of a new well, which was completed in 1984.

The cumulative capacity of the four production wells installed at Scout Island is approximately 6,800 Igpm (512 L/s), based on the approximate capacities of the pumps which have been installed in the four wells.

In 2001, a fifth production well (PW-5) was constructed on the north shore of the lake, opposite Scout Island (Fig. 3). The maximum yield for this well was reported to be 1850 Igpm (140 L/s), bringing the total well capacity to about 5,780 Igpm (438 L/s) (EBA, 2001).

## 4.3 AQUIFER PARAMETERS

The initial production wells were pump tested by the Water Investigations Branch prior to installation of the permanent pumps. The results of these tests indicated a transmissivity of about $8.9 \times 10^{-2}$ $m^2/s$ and a storativity of $1 \times 10^{-4}$. The former value indicates a very permeable aquifer that should be capable of supplying very large quantities of water. The latter value is indicative of a confined to semi-confined aquifer, which is expected based on the silty sand, silt and till layers which overlie the aquifer.

Plotted data from the test of the fourth production well, as reported by Aquaterre Consultants Inc. (October 1984), were reviewed. This test indicated similar parameters to the above. The long term trend of the test drawdown was affected by the pumping of the nearby wells, but it appears that the pumping level reached a near constant level a short time after the test started, and that recovery was very rapid following the cessation of pumping. This response to pumping indicates that the aquifer is well recharged in relation to the test pumping rate.

Respective transmissivity and storativity values of $4.7 \times 10^{-2}$ $m^2/s$ and $7 \times 10^{-4}$ were estimated from the test of PW-5 (EBA, 2001). The lower transmissivity value likely reflects the presence of the north aquifer boundary in close proximity to this well.

## 4.4 SOURCES OF RECHARGE

There are three possible sources of groundwater recharge to the channel aquifer. In their estimated order of significance, these are:

i) Leakage from Williams Lake - Under pumping conditions, when the aquifer levels are drawn down more than a few metres below the elevation of the Lake, leakage from the Lake into the aquifer is expected to be very significant. Based on a hydraulic head difference between the aquifer and the Lake of about 6m over a 5 $km^2$ area (approximately 50% of the lake), an average aquitard thickness of about 15m, and an aquitard hydraulic conductivity of $5 \times 10^{-8}$ m/s, the current rate of lake leakage into the aquifer is estimated to be in the order of 100 L/s.

ii) Groundwater flow from the valley slopes - The presence of some productive wells completed in the bedrock which surrounds the Lake indicates the potential for significant groundwater flows from the valley slopes towards the aquifer beneath Williams Lake. Under natural flow conditions (non-pumping conditions), these groundwater flows would likely discharge into the aquifer and then to surface (i.e. into the Lake). However, under pumping conditions, this recharge would be diverted by the production wells.

The average annual recharge rate to groundwater on the slopes above the Lake is estimated to be about 20mm/year, or about 5% of average annual precipitation. The recharge area is approximately 8 km long by 6 km wide, or 48 $km^2$. Using these rates and areas, average annual recharge to the groundwater flow regimes beneath the north and south valley slopes is estimated to be about 30 L/s.

iii) Flow Into Channel Aquifer from Upstream Tributary Aquifers - Aquifers which continue up the San Jose and Borland Creek Valleys have large catchment areas and tremendous recharge potential. The hydraulic capacity of these aquifers is therefore the limiting factor in terms of recharge which they can deliver to the channel aquifer beneath Williams Lake. As noted above, productive aquifers have not been encountered beneath Candycane I.R. No. 1. Recharge from this source is therefore expected to represent a minor component of the aquifer water balance, likely less than 20 L/s.

The total of these three recharge sources is about 150 L/s, equal to the average yield of about 2000 Igpm (150 L/ s) pumped from the well field in 2001.

## 4.5 AQUIFER VULNERABILITY

The continuous presence of silt, clay and/or dense till deposits over the aquifer will limit the rate of recharge to the aquifer, and also provide some ion exchange and adsorption capacity to retard the migration of contaminants. This confinement reduces, but does not eliminate, the vulnerability of the aquifer to contamination from surface sources.

Around the margins of the aquifer, bedrock will directly contact the aquifer sediments and various slope deposits may occur. The rate of recharge, and the risk of contamination entering the aquifer, is therefore likely to be slightly greater along the lower slopes of the valley than within the valley bottom.

## 4.6 RATIONALIZATION AGAINST AQUIFER MAPPING

Eight aquifers have been mapped in the immediate Williams Lake area by MWLAP (Table I). The extents of these aquifers, numbered 141 through 148, are shown on Fig. 6. Three of the aquifers are comprised of bedrock, and the other four are surficial sediments.

Aquifer 146 (Fig. 6) is the Williams Lake Aquifer in which the Scout Island well field is completed. The north-south aquifer extent interpreted by MWLAP is similar to that shown on Fig. 3, but the east-west extent shown on Fig. 3 is much greater, as the aquifer is assumed to be contiguous with other aquifers mapped along the valley. The golf course well and TW00-03 confirm that the aquifer extends further downstream than shown on Fig. 6, but the upstream extent is inferred. The depth of the aquifer downstream of Scout Island, and upstream of TW00-03, is also inferred to be greater than indicated by the well logs (Figs. 4 and 5).

All the aquifers in the vicinity of Williams Lake have been classified as low vulnerability, based on the level of confinement. This is consistent with the results of this study.

# 5. WELL FIELD PERFORMANCE AND WATER QUALITY

## 5.1 HISTORICAL SCOUT ISLAND WELL FIELD PRODUCTION

The rate of groundwater extraction since 1971, when PW-1 was commissioned, has steadily increased from an annual average of about 500 Igpm, to about 2000 Igpm from 1997 through 2001 (Fig. 7). Monthly averages prior to 1994 ranged from 1000 Igpm in the winter months, to 2000 to 2500 Igpm in the summer months. Since 1994, average winter flows have increased to about 1500 Igpm, and summer month flows have increased to 3000 Igpm.

Drawdown monitored in Observation Well No. 88 since 1971 displays a constant increasing trend. By 2001, total drawdown had reached 12m (Fig. 7). There is a discontinuity in the drawdown trend in 1992 that should be investigated, as it appears that the measurement datum may have changed at this time. If the measurement datum did change, total drawdown may be as much as 4m greater than indicated.

Specific capacities (the well production rate divided by the drawdown required to achieve that flow) have decreased since the mid 1980's (Fig. 7). From 1972 to 1987, the specific capacity varied from about 175 to 200 Igpm/m. The specific capacity calculated from late 1991 data is 112 Igpm/m, but the observation well data during this period are suspect. Following the discontinuity in the data, specific capacities have decreased from 194 Igpm/m in 1992 to 152 Igpm/m in 2001.

The increasing drawdown trend is partially explained by the increasing pumping rate trend. If there was no datum change in or around 1992, and data for the previous two years were erroneous, the trend appears to have flattened off between 1986 and 1992, a period of relatively constant demand. This would indicate that the aquifer was being adequately recharged at the ambient average pumping rate of about 1300 Igpm. If the measurement datum in Observation Well No. 88 was changed in 1992, this may not be the case.

Water demand was constant at about 2000 Igpm between 1997 and 2001. During this period, the drawdown and specific capacity displayed a constant declining trend (Fig. 7), indicating that water was being removed from aquifer storage, and that an equilibrium between recharge and well withdrawals had not been attained.

Drawdown over the past five years has averaged about 0.4m/year. The surface area of the aquifer is about 10 $km^2$. The aquifer has not likely drawdown to become unconfined in any areas, so the specific yield is expected to be quite low, certainly less than 1%. Even if a 0.4m/year drawdown and 1% specific yield are applied to the entire aquifer area, the annual volume of water removed from storage is only equivalent to $10 \times 10^6 \times 0.4 \times 0.01 = 40{,}000\ m^3$. This represents an average flow of only 1.3 L/s over the year.

The storage calculation indicates that most of the well yield is being derived from ambient recharge, whereas the drawdown trend in Observation Well No. 88 indicates storage is a significant component. While the risk that the aquifer is currently being over pumped and that yields will decline as water is removed from storage is considered to be very slight, the response displayed by the aquifer does need to be quantified and explained. A program to assess the aquifers sustainability is discussed in Section 8.4.

## 5.2 WATER QUALITY

Water chemistry data available for the production wells are summarized in Table II and plotted in Appendix A.

Based on the data summarized in Table II, Scout Island Well Field water can be characterized as very hard with a sodium-magnesium-calcium bicarbonate-sulphate chemistry. The water has a very high total dissolved solids concentration (TDS) (typically greater than 450 mg/L), and sometimes exceeds the 500 mg/L Aesthetic Objective (AO) in the Guidelines for Canadian Drinking Water Quality (GCDWQ) (Health Canada, 2002). Manganese concentrations generally fluctuate between 0.1 to 0.25 mg/L, above the AO of 0.05 mg/L.

All health based parameters for which chemical analyses were performed meet GCDWQ criteria. However, sodium concentrations typically range between 37 and 60mg/L, above the 20 mg/L threshold recommended for persons who require sodium restricted diets.

There is very little data on metal concentrations. Detailed analysis suites may have been performed when the original four wells were constructed, but this data was not located or compiled during this study. A complete suite of metals was analysed on two samples collected during the more recent test of PW-5, and also on a sample from TW00-03. These results indicated that metals are present at concentrations well below Maximum Acceptable Concentrations (MAC's), including arsenic at 0.006 to 0.008 mg/L (arsenic MAC = 0.025 mg/L).

Nutrient loading from the San Jose watershed has caused eutrophication of Williams Lake (McKean et al, September 1986). This is attributed primarily to the phosphorus loading. No data are available for the nitrate concentration in Williams Lake, which has a greater significance with regard to human health, but it is expected that nitrate concentrations would be very low. Nutrient concentrations in the well water samples are all very low (Tables III and IV), indicating that the chemistry of the groundwater has not been noticeably impacted by nutrients in locally recharged groundwater, or leakage from Williams Lake.

Time plots of the available chemistry data for production wells PW-1 through PW-4 are presented in Appendix A. Trends vary between wells and parameters, but overall:

- Well water concentrations are greater than average lake water concentrations, and
- Well water concentrations often displayed an increasing trend into the early 1990's, but are now trending lower and are approaching lake concentrations.

Iron is an exception, with concentrations lower than the typical range recorded for Williams Lake.

It appears that over time, the quality of well water will slowly approach, but not necessarily reach, the typical range of chemistry displayed by Williams Lake.

One parameter of particular interest is chloride. Lake concentrations are typically less than 2 mg/L. Concentrations in Observation Well #88 averaged about 3.5 mg/L prior to 1986 (McKean et al, September 1986). Chloride concentrations in the production wells are not currently monitored, but PW-5 and TW00-03 were sampled during the 2000/2001 testing program. Concentrations were about 6.5 and 20 mg/L, respectively. The presence of elevated chloride concentrations in the wells, relative to the lake may be due to natural background chemistry, or may indicate a slight impact from road salt or other contaminant sources.

# 6. CAPTURE ZONE ANALYSIS

The well capture zone must be determined to provide the physical boundaries for the well protection planning process. There are a number of ways to estimate the capture zone, ranging from recharge area calculations to analytical equations to numerical modelling. In this instance, recharge from Williams Lake represents the largest potential recharge source. Numerical modelling is the only method that can include this recharge source in a quantitative manner, and allow for some calibration against observed data. A numerical modelling method was therefore used for this study.

## 6.1 NUMERICAL MODELLING

A three-dimensional model of groundwater flow for the project area was developed to back-analyze the current flow regime. The Visual MODFLOW modelling code (Version 2.8.2.22) developed by Waterloo Hydrogeologic, Inc., of Waterloo, Ontario, Canada, was used for this study. Visual MODFLOW is based on the USGS MODFLOW code, which simulates groundwater flow in three-dimensions using the finite-difference method, either in steady-state or transient mode. MODFLOW uses a block centred grid system in which nodes are positioned at the centre of the finite-difference cells. The vertical dimension is simulated by defining layers within the finite-difference mesh.

### 6.1.1 Model Configuration and Boundary Conditions

A finite-difference mesh was constructed to represent an 8.0 by 12.0 km area, as shown on Fig. B-1 (Appendix B). The modelled area was discretized into 157columns, 116 rows and four layers. Cell dimensions within the mesh ranged from 100m in the perimeter areas to 25m in the Scout Island area. The various hydrogeological units in the Williams Lake area were represented in the model, and varying hydraulic conductivity values were assigned to the different material types. Uniform specific yield and specific storage values were applied to all the material types.

A plan of the project area was imported into the model, so that the extent of the lake and the alignment of the rivers could be displayed as an overlay, to assist with model construction.

Constant head cells were assigned throughout the footprint of Williams Lake at an elevation of 567m. River nodes were applied along the alignments of the San Jose and Williams Lake Rivers to allow leakage to/from the model at these locations. A constant head cell was also assigned at the downstream edge of the model at the interpreted Williams Lake River elevation. Plans and sections illustrating the mesh geometry and boundary conditions are presented in Appendix B (Figs. B-1 to B-4).

Recharge was applied uniformly over the extent of the model as surface infiltration. A recharge rate of 17mm/yr was assumed, equivalent to about 4% of the total annual precipitation for the area.

Scout Island production wells PW-1 through PW-4 were included in the model along with the new production well PW-5.

Test wells TW00-2 and TW00-3, Observation Well No. 88 and the Williams Lake Golf and Country Club (WLGCC) supply well were all incorporated into the model as observation wells, to provide hydraulic head calibration points.

### 6.1.2 Model Calibration

The model was calibrated by performing a series of steady-state runs in which the precipitation recharge, and aquifer and aquitard hydraulic conductivities were varied, to achieve a good match with the TW00-03, TW00-02 and Observation Well No. 88 heads. The percent root mean square (% RMS) error, calculated by the model, was used to evaluate the degree of calibration achieved between observed and simulated heads. Generally, a % RMS error of less than 10% indicates a reasonable degree of calibration.

The model was calibrated for initial conditions (no pumping) and for three different aquifer stress rates (Scout Island Well Field pumping rates in 1980, 1988 and October 2000). A % RMS error of 3.9% was achieved for the October 2000 case (Fig. B-5).

The Zone budget feature in the Visual MODFLOW program provides the ability to calculate flows in or out of the model at various boundary conditions, or across any geographical boundary. This feature was used to compute leakage from the lake, leakage to/from the river, and flow towards the wells beneath the western shore of the lake. Flows were computed for the four aquifer stress levels that were back-analyzed, and for one predictive simulation.

Results of the steady-state calibration are summarized in Tables B-1 to B-3, in Appendix B.

## 6.2 TIME OF TRAVEL ANALYSIS

The reverse particle tracking module in the Visual MODFLOW program was used to assist with the analysis of travel times and flowpaths for groundwater reporting to the Scout Island production wells. Particles introduced at the well were backward tracked to delineate their probable flow path and provenance. A series of particle pathway plots are presented in Figs. B-6 to B-9 (Appendix B), to illustrate the original flow path through the aquifer prior to development of the well field, and to show how the capture zone for the well field has expanded as the well field yield has increased.

A predictive simulation was performed for an average annual well field withdrawal rate of 2200 Igpm. Five, ten and fifty year capture zones were interpreted from this simulation, using the backward particle tracking method. Simulated extents of the five, ten and fifty year capture zones are shown on Fig. 8. The extent of the simulated five year capture zone is about 700m downstream (i.e. west) of PW-3. The ten and fifty year capture zones extend downstream about 1100m and 2300m, respectively. For practical planning purposes, the 50 year capture zone can be considered the boundary for the well protection planning process.

# 7. CONTAMINATION SOURCE ANALYSIS

Potential sources of contamination which could impact the aquifer beneath Williams Lake include nutrient loading in the lake water, non-point sources of contamination associated with residential land and transportation corridors, and point sources of contamination associated with industrial or commercial land use.

Most of the land within the Well Protection Area (fifty year capture zone) is either lake, unzoned land or acreage reserve. A large portion of the remaining land is zoned as either residential or commercial. Contaminant sources within these areas would generally include septic tanks, garden fertilizers and other non-point sources of contamination. Some underground storage tanks would also be present in these areas, but current regulations and practices mitigate the risk associated with active facilities of this type.

The greatest concern relative to aquifer water quality is the area of industrial zoned land on the south side of the Williams Lake River, downstream of the Scout Island Well Field (Fig. 8). Although this land is located downgradient of the well field, it lies directly above the aquifer, and a large proportion of this area is included within the ten year capture zone (Fig. 8).

The aquifer is considered to have a low vulnerability to surface sources of contamination. Risk presented by contaminants with low mobility (most metals and heavy hydrocarbons) is therefore considered to be low, particularly for accidental spills(as opposed to chronic leaks), where contamination occurs over a relatively short time interval. A greater risk is presented by mobile contaminants (e.g. nitrate, volatile hydrocarbons, salts), particularly where these originate from a chronic source (e.g. septic tanks, leaking tanks, leaching salt piles, contaminated sites). With the exception of the former, the chronic sources can all be categorized as point sources.

Potential contamination sources within the Scout Island Well Field capture zone are shown on Fig. 8. These sources are described below.

## 7.1 POINT SOURCES

Seven registered contaminated sites are included within the ten year capture zone, and an additional eight sites are included within the fifty year capture zone. Site locations are shown on Fig. 8, and the list of contaminants reported for each site is presented on Table III. There may also be other contaminated sites, associated with historical land use by previous property owners, that are not currently registered with MWLAP.

Diesel and gasoline are the most common contaminants, and waste oil has been reported for one site. Road salt and solvents associated with paints have also been reported. Fuels can be a source of some relatively mobile chemicals that present serious health risks (e.g. benzene, napthalene). Other contaminants, such as salt, present a lower health risk.

A downward hydraulic gradient throughout the well capture zone provides a mechanism to transport contaminants down through the confining layer and into the underlying aquifer. While many of the contaminants are not very soluble or mobile, and the migration of some mobile contaminants may be significantly retarded in the confining layer, it must be expected that some chemicals would eventually reach the aquifer if the source is present for a sustained period. Contaminated soil and groundwater within all of the above registered sites, while under various stages of assessment and remediation, are considered chronic contaminant sources. The sites shown on Fig. 8 therefore present a risk to the Scout Island Well Field water supply.
Risks associated with each contaminated site need to be assessed, to determine the implications to public health. Preliminary recommendations for managing the risks presented by contaminated sites are provided in Section 7.4.

In addition to the above registered sites, there may be some other potential point sources of contamination within the well capture zone. Current regulations and practices will largely mitigate any risks associated with active sites that contain hazardous chemicals, but all potential contaminant point sources within the fifty year capture zone should be identified and assessed as part of this Well Protection Plan. Potentially contaminated sites that result from a previous property use and are not currently registered therefore need to be identified, and subjected to at least a preliminary risk assessment. Historical land uses of concern include service stations, automotive repair or machine shops, dry cleaners, etc.

## 7.2 NON-POINT SOURCES

### 7.2.1 Linear Sources

Linear sources of contamination within the well capture zone include the BC Rail line and Highways 97 and 20 (Fig. 8). Goods transported along these corridors will include soluble and insoluble liquid chemicals that could readily infiltrate into the ground if any spills do occur. This source of contamination is judged to represent a low risk, as small incidental spills that escape detection would be unlikely to penetrate the aquitard, and larger spills would be reported and remediated to manage the risk.

### 7.2.2 Residential Areas

Contaminants that can originate from residential areas include nutrients and pathogens from septic tank systems, garden fertilizers and household chemicals. The potential impact due to nutrient loading from septic systems within the Well Protection Area would be minimal. Potential nitrate concentrations would be diluted to less than 1 mg/L-N just based on the well pumping quantity alone, and attenuation provided along the flow path, by the confining layers is expected to maintain nitrate impacts at or only slightly above detectable levels. Time of travel, and the aquifer confinement, will protect the water source from pathogens and garden chemicals, which typically have short survival times or half lives, in comparison to the travel time to the well.

Residential areas are not considered to present a significant risk to well water quality.

### 7.2.3 Agricultural Areas

Agriculture activities do not occur within the Well Protection Area on a significant scale, and are judged to present a very low risk to well water quality.

### 7.2.4 Golf Courses and Parks

Pesticide use in parks and golf courses is not considered a significant risk to water quality, as pesticides typically have short half lives, and are unlikely to persist long enough to reach the aquifer, or seep to the well. It is highly unlikely that any pesticides would be detected at the wells.

## 7.3 WILLIAMS LAKE

Based on the modelling results (Table B-2) and water balance calculations (Section 4.4), seepage from Williams Lake accounts for about two thirds of the flow produced by the well field. As such, any changes to Williams Lake water quality will be reflected in the chemistry of the well water.

Problems with Williams Lake water quality are related to eutrophication and associated algae growth. Algae growth is related primarily to very low phosphorus concentrations which do not have implications for human health.

Filtration provided by the lake bottom sediments protects the aquifer from suspended matter such as algae. The dissolved water quality in Williams Lake is currently potable, and the impact most likely to occur in response to land use changes is an increase in nutrient concentrations. At present, nitrate concentrations in the well water are at or below detection limits, so a small increase in nutrient concentrations does not present a potability risk.

The Williams Lake watershed covers a 2,240 $km^2$ area. The quality of runoff from this large area is not likely to change significantly in response to incremental changes in land use, as any changes would be limited to small proportions of the total watershed. Changes that do occur are therefore expected to have gradual onset that would be identifiable in a long term monitoring record. Policies could be developed to manage any water quality problems that do develop over time.

Some significant impacts could occur more suddenly, in response to intensive land uses or spills. These would be considered point sources that could be identified and mitigated, as required.

The flushing rate of the lake is about 0.62 times/year (McKean et al, 1986). This short flushing period would reduce the risk associated with any sudden changes in lake water quality, as the quality would improve quickly after a contaminant source was removed. Aquifer water quality impacts would then be very diluted in relation to the lake impact, as any aquifer recharge that occurred over a relatively small time interval would mix with recharge that occurs over many decades.

Based on the above, potential changes to the quality of Williams Lake water are not expected to have a significant impact on well water quality, and any that do occur could be identified and managed accordingly.

## 7.4 PRELIMINARY RISK MANAGEMENT RECOMMENDATIONS

A number of practices or procedures should be implemented to manage the groundwater contamination risk within the well capture zone. Monitoring is the first priority, as it can be implemented unilaterally and would directly measure any impacts to well water quality. Source control strategies are also required, but require consultation with, and acceptance by, the various stakeholders with interests in the Well Protection Area.

### 7.4.1 Monitoring

A monitoring program should be implemented to sample for the most mobile contaminants identified within the well capture zone, and a range of indicator parameters for the probable contaminants. Groundwater samples should be collected from PW-1, PW-3, PW-5 and a proposed new monitoring well to be constructed between the well field and the industrial area (Fig. 8). In addition, surface water samples should be collected from Williams Lake River at the Highway 20 bridge.

Groundwater sampling should be conducted in the spring and fall, and Williams Lake River sampling should occur in the fall. Parameters for the groundwater samples should include:

| | |
|---|---|
| Monitoring well, PW-1, PW-3 and PW-5 (2/year): | Chloride, sodium, nitrate |
| Monitoring well, PW-1, PW-3 and PW-5 (1/year): | Complete potability, VOC scan, LEPH/HEPH, PAH's |

Parameters for the River should include: Chloride, sodium, nitrate, phosphorus

Note: HEPH = heavy extractable petroleum hydrocarbons, LEPH = light extractable petroleum hydrocarbons, PAH = polycyclic aromatic hydrocarbons

It is expected that chloride, a highly mobile contaminant present beneath Registered Contaminated Site 0725, would report to the well field in advance of other contaminants. If a chloride front has arrived, the above monitoring would provide some resolution as to the likely travel times involved, and the mixing rate of water derived from areas west of the well field versus the other directions. PW-5 data would identify whether any identified contamination originates from the commercial area to the north of the Lake.

If any contamination issues are identified, the program would have to be expanded, to provide data to further delineate the sources and design remedial strategies.

7.4.2 Inventory Validation

Once a Well Protection Planning Committee has been established, local knowledge should be tapped to obtain additional information on the area history. This information would be used to validate and/or expand on the list of contaminants and contaminant sources listed in Table III.

If necessary, the monitoring recommendations provided above would be amended to address any concerns identified with the new information.

### 7.4.3 Consultation

Contaminated sites within the Well Protection Area are judged to present the greatest risk to water quality in the Williams Lake Aquifer. Persons responsible for the sites listed in Table III should be provided with a copy of the plan that delineates the Scout Island Well Protection Area, and informed that their sites are located within the protection area. A request should then be made for information on:

- The current status of the site relative to contamination extent and remediation measures, and
- Any risk assessments that may have been performed to address potential impacts to the Williams Lake Aquifer.

This information should be incorporated into the database, and information gaps should be identified. A third party should then review the database, and provide an opinion on whether additional assessments or assurances should be requested from the property owners.

Transportation corridors within the Well Protection Area are not considered to present a significant contamination risk. Nonetheless, BC Rail, the local Ministry of Transportation and Highways, and the representative for the local highways maintenance contractor should be provided with a plan that shows the extent of the Scout Island Well Protection Area, and requested to provide information on:

- Any risk assessments that may have been performed to address potential impacts to Williams Lake and groundwater in the area,
- Spill contingency plans that are in effect, and
- Pesticide practices that are undertaken along those portions of the transportation corridors that are within the Well Protection Area, and any associated pesticide management plans.

If spill contingency plans have not been prepared, the appropriate authority should be encouraged to do so. Existing and new spill contingency plans should include a requirement to notify the City if spills occur within the Well Protection Area.

# 8. WELL PROTECTION PLANNING PROCESS

The well protection planning process should be initiated on two fronts. A Well Protection Planning Committee (WPPC) should be formed, to develop a practicable plan for the community, and then see that it is implemented. The monitoring program recommended in Section 7.4 should also be implemented immediately, to provide data on water quality beneath the industrial area included in the west portion of the Well Protection Area.

As evident on Fig. 8, the entire ten year capture zone and most of the developable land within the Well Protection Area are inside the City's municipal boundary. The City must therefore have the greatest representation on the WPPC. Representation is also required from the population serviced by the wells, and from the Ministries that regulate industry or administer government services in the area. Recommendations for the WPPC membership and the scope of the planning process are provided in the following.

## 8.1 WPPC MEMBERSHIP

It is recommended that the WPPC membership include all or most of the following persons. It would be beneficial if most of the members have resided in the area for a considerable time, and it would be preferable to have a few people on the committee who have resided in the area for at least three decades, to provide invaluable historical knowledge.

- City of Williams Lake
    - Planning Department representation
    - Council representation (one and one alternate)
- Cariboo Regional District
    - Planning Department representation
    - Council representation
- Ministry of Transportation and Highways
- Ministry of Water, Land and Air Protection
    - Environmental Protection Division representation
- Ministry of Health
    - Local Environmental Health Officer or Drinking Water Officer

- Ministry of Agriculture
- Ministry of Forests
- Industry Representative
  - BCR, and/or an oil company
- Public Representation
  - Two or three persons with good local knowledge and/or a background in public health or public facilitation.

After the committee has been formed, members should be provided with a copy of this report to become familiar with the issues.

## 8.2 WORKSHOP

The contents of this report will be presented at a workshop attended by Mr. Holmes and the WPPC. A recommended table of contents for the Well Protection Plan, and some preliminary text addressing specific issues, will be developed and presented at the workshop. The committee will then have to decide what well head protection measures are to be implemented, and which risks should be assessed in greater detail. Further assessment would likely require assistance from committee members with the appropriate experience to evaluate the concerns identified in the hydrogeological study, and/or consultation with various stakeholders and landowners in the Well Protection Area.

## 8.3 SCOPE OF PLAN

A large number of issues must be addressed by the plan, including agricultural and forestry practices in the Williams Lake Watershed, maintenance practices on the golf course, and on-site servicing of residential land along the south and north shores of Williams Lake. While these potential sources of contamination are all considered to present little or no risk to the Scout Island wells, they need to be documented and addressed in the plan. The principal focus of the plan will be the risk presented by the industrial land at the west end of the Lake. This may have to be addressed in some detail, and will almost certainly require the cooperation of the landowners in the area.

A public participation program should also be developed, to inform persons of the well protection boundaries and to get some feedback on local concerns and priorities. As issues regarding water supplies can often become emotional, it is important that any information released to the public is accurate and well verified, and compatible with the envisioned direction of the Well Protection Plan.

Implementation of the plan will likely include all or some of the following:

- Publication of a formal plan document,
- Public information and notification, by signage and/or newspaper advertisements,
- Land use control by-laws,
- Consultation and negotiation with property owners regarding chronic contamination issues (this could also result in by-laws, if necessary),
- Emergency preparedness plan, to deal with spills and other random events that could present a risk to well water quality, and
- A monitoring program.

## 8.4 MONITORING PROGRAM

The water quality monitoring program outlined in Section 7.4.1 should be implemented as soon as possible. An initial suite of samples should be collected from three of the existing production wells (PW-1, PW-3 and PW-5) and submitted for the detailed list of contaminants. This should be done prior to installing the proposed monitoring well, unless the monitoring well can be installed within a relatively short timeframe.

Numerical modelling and water balance calculations for the aquifer indicate that the majority of the water pumped by the wells must be seepage from Williams Lake and the River downstream, and ambient groundwater recharge above the north and south sides of the Lake. Water derived from the depletion of aquifer storage is calculated to be minimal. However, the drawdown trend displays a constant declining trend, indicative of storage depletion and/or constantly increasing demand. This trend should be monitored closely over the next few years, particularly during any periods of constant or declining demand, to see if it flattens or even starts to recover. In addition, the possibility that the datum elevation for this well was adjusted about the beginning of 1992 needs to be researched, as this has implications to the interpretation of the drawdown data.

Once sufficient data are available (in the order of three years), the drawdown status of the aquifer should be reviewed, and the sustainability of the aquifer should be assessed.

# 9. SUMMARY

The Scout Island Well Field has been developed in a confined aquifer underlying Williams Lake. It is estimated that about two thirds of the water pumped from the aquifer is induced leakage from Williams Lake. As such, well water quality over the long term will largely reflect Williams Lake water quality.

Williams Lake flow is recharged over a 2,240 $km^2$ catchment area that is largely forest and range land. Any changes to water quality that do occur are expected to be limited to subtle incremental changes in nutrient concentrations, over an extended period of time. These expected changes do not present a risk to the Scout Island wells, but good practice mandates that land use activities within the watershed be monitored, as part of the Well Protection Plan.

Approximately one third of the recharge to the Scout Island Well Field is derived from local recharge. Contamination leached to the aquifer by this recharge represents the principal risk to aquifer water quality. Most of the developable land contained in the Well Protection Area is inside the City's boundary. The City should therefore have the ability to regulate land use in areas where contamination risks are identified.

The confined character of the aquifer will protect groundwater quality to a large degree, but industrial and commercial land use within the Well Protection Area, and particularly within the five and ten year capture zones, is a cause for concern. The Well Protection Plan must characterize and quantify the risk presented by contamination beneath registered contaminated sites, and possibly unknown contamination beneath other sites. This will require considerable involvement by members of the Well Protection Planning Committee, and consultation and possibly negotiation with some of the property owners in the Well Protection Area. A monitoring program will also be required.

The Well Protection Planning Process should be initiated by forming a Well Protection Planning Committee and implementing the monitoring program. A workshop should be conducted after the committee has been formed and some initial monitoring data has been obtained. The purpose of the workshop would be to formally present the contents of this report, to reach a consensus on the objectives and scope of the plan, and to develop a plan framework and schedule.

Respectfully submitted,

PITEAU ASSOCIATES ENGINEERING LTD.

PROFESSIONAL ENGINEER
PROVINCE OF BRITISH COLUMBIA
ANDREW T. HOLMES

Oct 28/03

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Matthew D. Pye, P. Eng.

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# TABLES

## TABLE I
## SUMMARY OF AQUIFERS IN IMMEDIATE WILLIAMS LAKE AREA

| AQUIFER # | LOCATION DESCRIPTION | MATERIALS | CLASSIFICATION | RANKING VALUE | SIZE ($km^2$) | VULNERABILITY |
|---|---|---|---|---|---|---|
| 093B/01 141 | Between Williams Lake and Missioner Creek | Bedrock | IIIC | 8 | 18 | Low |
| 093B/01 142 | Southwest side of Williams Lake | Bedrock | IIC | 7 | 1.7 | Low |
| 093B/01 143 | Southwest side of Williams Lake | Sand and Gravel | IIC | 8 | 0.9 | Low |
| 093B/01 144 | Southeast side of Williams Lake | Sand and Gravel | IIC | 7 | 0.4 | Low |
| 093B/01 145 | Northeast side of Williams Lake | Sand and Gravel | IIIC | 7 | 1 | Low |
| 093B/01 146 | West and northwest side of Williams Lake | Sand and Gravel | IC | 11 | 3.3 | Low |
| 093B/01 147 | Hill southwest of Williams Lake townsite | Sand and Gravel | IC | 9 | 0.3 | Low |
| 093B/01 148 | Hill southwest of Williams Lake townsite | Bedrock | IIIC | 9 | 31 | Low |
| 093B/01 149 | Chimney Creek Valley | Sand and Gravel | IIIC | 8 | 7.3 | Low |
| 093B/01 150 | South of Williams Lake on Dog Creek Road | Sand and Gravel | IIC | 8 | 1.2 | Low |

Notes: 1) From MWLAP aquifer mapping data base.
2) Locations are shown and classifications are described on Fig. 6.

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## TABLE II
## SUMMARY OF CHEMISTRY DATA FOR PRODUCTION WELLS

**PW-1**

| PARAMETER | Jul-71 | May-76 | Feb-82 | Mar-87 | Mar-88 | Jun-89 | Jun-93 | Sep-93 | Dec-93 | Apr-94 | Aug-94 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Alkalinity Phenol (pH 8.3) | | | | | | | | | < 0.5 | < 0.5 | |
| Alkalinity Total (pH 4.5) | | | | | | | | | 428 | 411 | |
| Alkalinity, Bicarbonate | | | | | | | | | | | |
| Alkalinity, Carbonate | | | | | | | | | | | |
| Chloride | | | | | | | | | | | |
| Conductivity (umhos/cm) | | | | | | | | | 858 | 858 | |
| Dissolved Solids | 500 | 730 | 558 | 610 | 667 | 511 | 609 | 612 | 667 | 638 | 490 |
| Fluoride | 0.18 | | < 0.3 | 0.11 | 0.53 | 0.33 | 0.6 | 0.4 | 0.4 | 0.5 | 0.4 |
| Hardness | 363 | 496 | 362 | 473 | 469 | 491 | 353 | 429 | 506 | 506 | 486 |
| Nitrate | | | | | 0.016 | 0.003 | | | 0.019 | < 0.003 | |
| Nitrite | | | | | | | | | < 0.003 | < 0.003 | |
| Non Coliform Colonies | | | | | | | | | | | many |
| pH | 7.8 | 7.7 | 7.55 | 7.94 | 7.78 | 8.1 | | | 7.99 | 7.45 | |
| Sulfate | | | 115 | 162 | 143 | 160 | | | 122 | 154 | |
| Total Calcium | | | 36.3 | 46.7 | 52 | 52.9 | | | 54 | 54.95 | |
| Total Coliform (CFU/100mL) | | | | | | | | | | | < 1 |
| Total Iron | 0.18 | | 0.15 | 0.2 | 0.08 | < 0.01 | 0.036 | < 0.005 | 0.052 | 0.09 | < 0.03 |
| Total Magnesium | | | | | | | | | 90.1 | 89.59 | |
| Total Manganese | | | 0.1 | 0.14 | 0.16 | 0.06 | 0.129 | 0.158 | 0.195 | 0.201 | 0.15 |
| Total Potassium | | | | | | | | | | 6.32 | |
| Total Phosphate | | | | | | | | | 0.335 | 0.224 | |
| Total Sodium | | | | | | | | | 55.7 | 61.2 | |
| Turbidity (NTU) | | | | | | | | | | | |

| PARAMETER | Jan-95 | Oct-95 | Jan-97 | May-97 | Jul-97 | Sep-98 | Mar-99 | Sep-99 | Apr-00 | Feb-00 | Jan-02 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Alkalinity Phenol (pH 8.3) | < 0.5 | | < 2 | | | | | | | | 0 |
| Alkalinity Total (pH 4.5) | 327 | | 367 | | | | | | | | 296 |
| Alkalinity, Bicarbonate | | | | | | | | | | 362 | |
| Alkalinity, Carbonate | | | | | | | | | | 0 | |
| Chloride | 3.6 | | | | | | | | | | |
| Conductivity (umhos/cm) | 702 | | 919 | | | | | | | 848 | 622 |
| Dissolved Solids | 458 | 672 | 647 | 598 | 660 | 623 | 645 | 20 | 578 | 536 | 398 |
| Fluoride | 0.2 | 0.3 | 0.4 | 0.4 | 0.5 | 0.4 | 0.4 | 0.4 | 0.4 | 0.33 | 0.28 |
| Hardness | 320 | 378 | 377 | 441 | 369 | 400 | 377 | 379 | 389 | 373 | 255 |
| Nitrate | < 0.003 | | < 0.003 | | | | | | | < 0.03 | 0.004 |
| Nitrite | < 0.003 | | < 0.003 | | | | | | | < 0.03 | < 0.03 |
| Non Coliform Colonies | | | 30 | many | | many | | | 4 | 7 | 0 |
| pH | 7.68 | | 7.8 | | | | | | | 7.97 | 8 |
| Sulfate | 61 | | 144 | | | | | | | 130 | 43 |
| Total Calcium | 36.5 | | 38.4 | | | | | | | 40.3 | 27.1 |
| Total Coliform (CFU/100mL) | < 1 | < 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total Iron | 0.06 | < 0.07 | 0.088 | 0.01 | 0.054 | < 0.008 | 0.09 | < 0.005 | 0.077 | 0.047 | 0.016 |
| Total Magnesium | 55.6 | | 69.5 | | | | | | | 66.1 | 45.6 |
| Total Manganese | 0.133 | 0.152 | 0.145 | 0.14 | 0.146 | 0.138 | 0.167 | 0.149 | 0.156 | 0.143 | 0.097 |
| Total Potassium | | | 5.8 | | | | | | | 5.3 | 4.1 |
| Total Phosphate | 0.347 | | 0.215 | | | | | | | 0.253 | 0.231 |
| Total Sodium | 44.6 | | 56.3 | | | | | | | 50.8 | 39.68 |
| Turbidity (NTU) | 0.55 | | | | | | | < 0.2 | < 0.2 | 0.4 | < 0.2 |

Notes:
1. Data prior to 1991 are from City of Williams Lake and Dayton & Knight paper files. More recent data on spreadsheet provided by the City.
2. Concentrations are in mg/L unless otherwise noted.

# TABLE II
# SUMMARY OF CHEMISTRY DATA FOR PRODUCTION WELLS

| WELL #2 | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **PARAMETER** | **Dec-71** | **Feb-82** | **Mar-87** | **Mar-88** | **Jun-89** | **Oct-90** | **Apr-91** | **Dec-92** | **May-93** | **Apr-95** | **Oct-97** | **Dec-98** |
| Alkalinity, Phenol | | | | | | | | < 0.05 | | | | < 0.5 |
| Alkalinity, Total | | | | | | | | 324 | | | | 329 |
| Conductivity (umhos/cm) | | | | | | | | 699 | | | | 688 |
| Dissolved Solids | 440 | 407 | 472 | 467 | 294 | 500 | 516 | 469 | 487 | 403 | 498 | 480 |
| Fluoride | 0.14 | < 0.3 | 0.15 | 0.44 | 0.33 | 0.18 | 0.3 | 0.1 | 0.15 | 0.3 | 0.4 | 0.3 |
| Hardness | 375 | 287 | 349 | 348 | 364 | 334 | 370 | 301 | 307 | 308 | 272 | 326 |
| Nitrate | | | | < 0.002 | < 0.002 | 0.007 | < 0.002 | < 0.003 | | | | < 0.003 |
| Nitrite | | | | | | | | < 0.003 | | | | < 0.003 |
| Non Coliform Colonies | | | | | | | | | | | many | |
| pH | 7.8 | 7.55 | 7.89 | 7.89 | 8.18 | 7.4 | 7.4 | 7.69 | | | | 8.06 |
| Phosphate | | | | | | | | 0.276 | | | | 0.224 |
| Sulfate | | 19.5 | 64.3 | 77 | 67 | 86 | 132 | 121 | | | | 130 |
| Total Calcium | | 32.8 | 38.8 | 42 | 41.8 | 35.7 | 37.8 | 34.9 | | | | 36.2 |
| Total Coliform (CFU/100mL) | | | | | | | | < 1 | | < 1 | 0 | 0 |
| Total Iron | 0.09 | 0.15 | 0.18 | 0.09 | < 0.01 | 0.09 | 0.06 | 0.074 | 0.115 | < 0.07 | 0.02 | < 0.008 |
| Total Magnesium | | | | | | | | 51.9 | | | | 57.1 |
| Total Manganese | 0.14 | 0.1 | 0.1 | 0.13 | 0.05 | 0.17 | 0.11 | 0.142 | 0.144 | 0.145 | 0.127 | 0.129 |
| Total Potassium | | | | | | | | 5.88 | | | | < 0.003 |
| Total Sodium | | | | | | | | 38.8 | | | | 39 |
| Turbidity (NTU) | | | | | | | | | | | | 0.3 |

Notes:
1. Data prior to 1991 are from City of Williams Lake and Dayton & Knight paper files. More recent data on spreadsheet provided by the City.
2. Concentrations are in mg/L unless otherwise noted.

# TABLE II
# SUMMARY OF CHEMISTRY DATA FOR PRODUCTION WELLS

| PW-3 | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PARAMETER | May-76 | Feb-82 | Mar-87 | Mar-88 | Jun-89 | Jun-90 | Jan-91 | Jul-92 | Jul-95 | Dec-95 | Aug-96 | Jan-98 | Apr-98 | Nov-01 | May-02 |
| Alkalinity, Phenol | | | | | | | | | | < 0.5 | | < 0.05 | | | |
| Alkalinity, Total | | | | | | | | | | 429 | | 428 | | | |
| Conductivity (umhos/cm) | | | | | | | | | | 946 | | 952 | | | |
| Dissolved Solids | 530 | 622 | 614 | 592 | 476 | 580 | 595 | 674 | 660 | 648 | 637 | 640 | 639 | 607 | 599 |
| Fluoride | < 0.5 | < 0.3 | 0.12 | 0.34 | 0.41 | 0.5 | | 0.26 | 0.4 | 0.3 | 0.4 | 0.66 | 0.3 | 0.389 | 0.35 |
| Hardness | 423 | 429 | 500 | 482 | 539 | 682 | | 440 | 261 | 430 | 435 | 400 | 354 | 400 | 359 |
| Nitrate | | | | < 0.002 | < 0.002 | < 0.002 | | | | < 0.003 | | 0.013 | | | |
| Nitrite | | | | | | | | | | < 0.003 | | < 0.003 | | | |
| Non Coliform Colonies | | | | | | | | | | many | | many | 6 | | 0 |
| pH | 7.8 | 7.6 | 7.78 | 7.84 | 8.18 | 7.62 | | | | 8.38 | | 7.79 | | | |
| Phosphate | | | | | | | | | | 0.062 | | 0.254 | | | |
| Sulfate | | 77.8 | 112 | 94 | 120 | 161 | | | | 116 | | 118 | | | |
| Total Aluminum | | | | | | | 0.08 | | | < 0.05 | | < 0.006 | | | |
| Total Barium | | | | | | | 0.02 | | | < 0.08 | | < 0.01 | | | |
| Total Calcium | | 46.6 | 52 | 55.4 | 60.4 | 72.5 | | | | 49.4 | | 30.7 | | | |
| Total Coliform (CFU/100mL) | | | | | | | | | < 1 | < 1 | | 0 | 0 | | 0 |
| Total Iron | 0.12 | 0.1 | 0.05 | 0.13 | < 0.01 | 0.24 | 0.1 | 0.11 | < 0.07 | 0.21 | 0.18 | < 0.008 | < 0.008 | 0.074 | 0.04 |
| Total Magnesium | | | | | | | | | | 73.1 | | 70.5 | | | |
| Total Manganese | 0.16 | 0.2 | 0.24 | 0.28 | 0.11 | 0.22 | | 0.24 | 0.36 | 0.296 | 0.261 | 0.251 | 0.24 | 0.231 | 0.245 |
| Total Potassium | | | | | | | | | | 6 | | 6.5 | | | |
| Total Silica | | | | | | | 12.4 | | | | | | | | |
| Total Sodium | | | | | | | | | | 49 | | 48.6 | | | |
| Total Strontium | | | | | | | 0.7 | | | | | | | | |
| Turbidity (NTU) | | | | | | | | | | | | | | 0.3 | 0.3 |

| PW-4 | | | | | |
|---|---|---|---|---|---|
| PARAMETER | Mar-87 | Mar-88 | Jun-89 | May-92 | Jul-02 |
| Alkalinity Phenol (pH 8.3) | | | | | |
| Alkalinity Total (pH 4.5) | | | | | 385 |
| Dissolved Arsenic | | | | | |
| Conductivity (umhos/cm) | | | | | 900 |
| Dissolved Solids | 630 | 659 | 470 | 506 | |
| Fluoride | 0.15 | 0.38 | 0.42 | 0.29 | 0.44 |
| Hardness | 508 | 524 | 503 | 400 | 363 |
| Nitrate | | < 0.002 | < 0.002 | < 0.002 | < 0.003 |
| Nitrite | | | | | < 0.003 |
| Non Coliform Colonies | | | | | > 200 |
| pH | 7.88 | 7.86 | 8.12 | 7.8 | 8.13 |
| Sulfate | 114 | 128 | 108 | 109 | 48 |
| Total Calcium | 46.5 | 52.2 | 52 | 38.1 | 37.3 |
| Total Coliform (CFU/100mL) | | | | | 0 |
| Total Iron | 0.6 | 0.09 | < 0.01 | 0.03 | 0.021 |
| Total Magnesium | | | | | 65.5 |
| Total Manganese | 0.09 | 0.17 | 0.06 | 0.12 | 0.133 |
| Total Phosphate | | | | | 0.257 |
| Total Potassium | | | | | 5 |
| Total Sodium | | | | | 41.5 |
| Total Solids | | | | | 593 |
| Turbidity (NTU) | | | | | 0.3 |

| | PW-5 | | TW00-03 |
|---|---|---|---|
| PARAMETER | 14-Feb-01 | 15-Feb-01 | 16-Oct-00 |
| Alkalinity Total (pH 4.5) | 350 | | |
| Dissolved Arsenic | 0.0058 | 0.006 | 0.008 |
| Choride | 6.3 | 6.5 | 20.4 |
| Conductivity (umhos/cm) | 612 | 615 | 1570 |
| Dissolved Solids | 379 | 365 | 1010 |
| Fluoride | 0.2 | 0.19 | 0.19 |
| Hardness | 308 | 317 | 645 |
| Nitrate | <0.005 | < 0.002 | 0.01 |
| Nitrite | <0.001 | <0.001 | 0.001 |
| Non Coliform Colonies | <1 | <1 | <1 |
| pH | 8.18 | 8.11 | 8.11 |
| Sulfate | 24 | 24 | 237 |
| Calcium | 20.1 | 22.4 | 79.1 |
| Total Coliform (CFU/100m | <1 | <1 | <1 |
| Dissolved Iron | <0.03 | <0.03 | 0.84 |
| Magnesium | 62.5 | 63.4 | 109 |
| Dissolved Manganese | 0.092 | 0.101 | 0.171 |
| Total Phosphate | | | |
| Potassium | 5.95 | 6.37 | 8.2 |
| Sodium | 37.2 | 38.7 | 128 |
| Total Solids | | | |
| Turbidity (NTU) | 0.3 | 0.1 | 3.5 |

Notes:
1. Data prior to 1991 is from City of Williams Lake and Dayton & Knight PAPER files.
3. PW-5 and TW00-03 data from EBA (2000 and 2001).
2. Concentrations are in mg/L unless otherwise noted.

## TABLE III
## SUMMARY OF REGISTERED CONTAMINATED SITES WITHIN POSSIBLE MUNICIPAL WELL FIELD CAPTURE ZONE

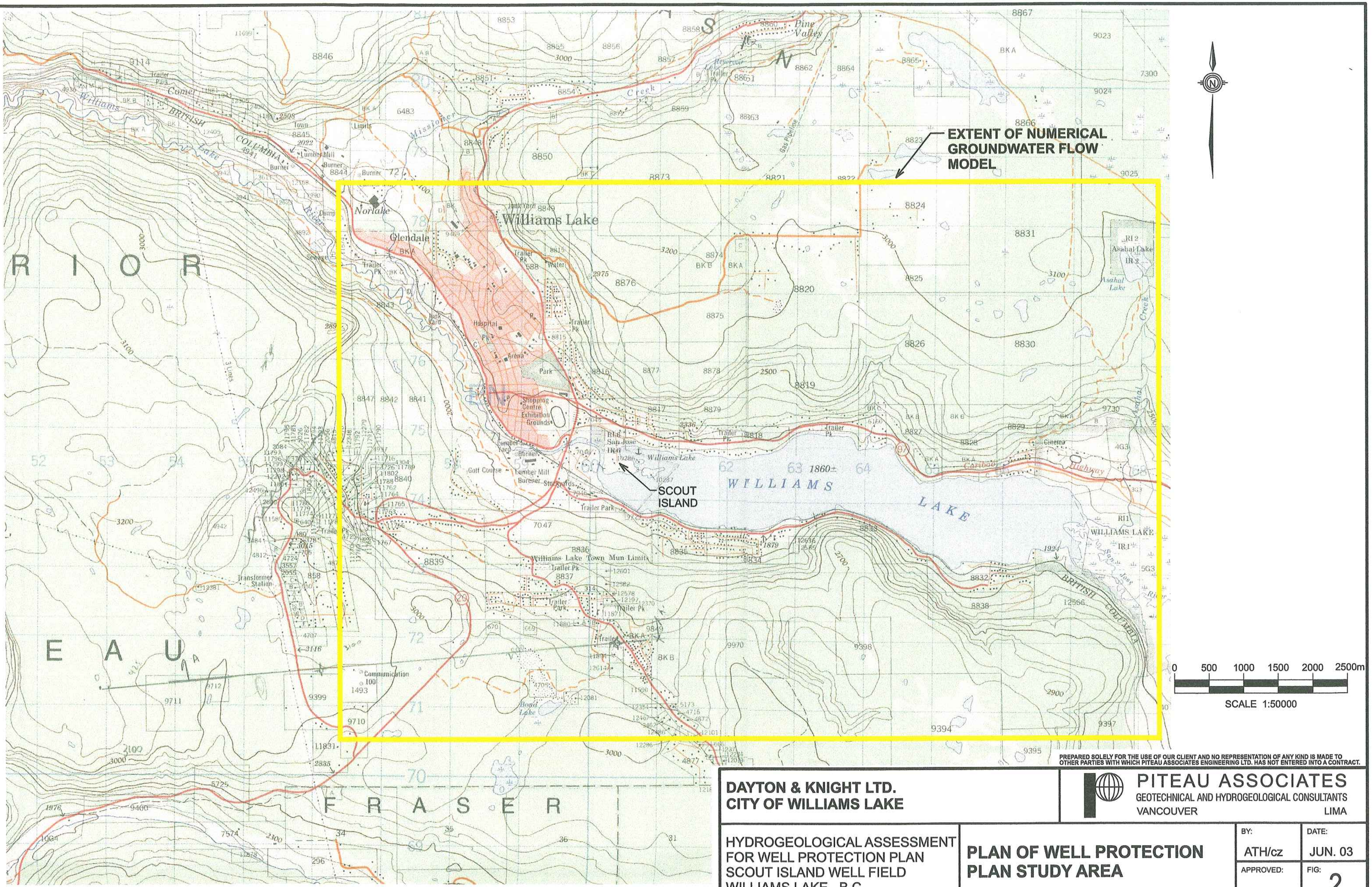
| CAPTURE ZONE LOCATION | MOE SITE ID | ADDRESS | CURRENT OWNER | CURRENT SITE USE | PREVIOUS SITE USE | POTENTIAL CONTAMINANTS | CURRENT STATUS |
|---|---|---|---|---|---|---|---|
| < 5 Year | 0000725 | 1010 BAGSHAW ROAD | Former Highway's Yard | Vacant | Highway's Yard | salt, fuel | Active - Under Remediation |
| | 0001821 | BAGSHAW and CHOW ROAD | Petrocan | Bulk Plant / Cardlock | n/a | diesel, gasoline | Active - Under Remediation |
| | 0004813 | 905 BAGSHAW ROAD | South Yard BCR | Rail yard | n/a | diesel | Active - Under Assessment |
| < 10 Year | 0000955 | 1238 BROADWAY AVE SOUTH | Shell | Gas Station | n/a | diesel, gasoline | Inactive - No Further Action |
| | 0007652 | 1708 BROADWAY AVE SOUTH | Super Save | Gas Station | n/a | diesel, gasoline | Active - Under Assessment |
| | 0007058 | 101-25 HODGSON ROAD | Chevron | Cardlock | n/a | diesel, gasoline | Active - Under Remediation |
| | 0000458 | 1020 SOUTH LAKESIDE DRIVE | Canadian Tire / Real Wholesale Club | Retail / Gas Bar | Bulk Plant | diesel, gasoline, chromium | Inactive - No Further Action |
| < 50 Year | 0000462 | 1024 BROADWAY AVE SOUTH | Adventure Charter | Charter Company Office | Gas Station | diesel, gasoline | Inactive - No Further Action |
| | 0006080 | 245 HODGSON ROAD | United Concrete | Concrete Plant | n/a | ? - zoning issue | Inactive - No Further Action |
| | 0004361 | 15 HIGHWAY 97 NORTH | Chevron | Gas Station | n/a | diesel, gasoline | Inactive - No Further Action |
| | 0004558 | 180 HODGSON ROAD | Lignum Ltd. Saw Mill | Saw Mill | BCR | waste oil, diesel, gasoline | Active - Under Remediation |
| | 0004691 | 4 BROADWAY AVE | National Car Rental | Car Rental | Gas Station | diesel, gasoline | Active - Under Remediation |
| | 0003928 | 598 MACKENZIE AVE SOUTH | Shell ? | | Forner Bulk Plant | | Active - Under Assessment |
| | 0001245 | 648 MACKENZIE AVE SOUTH | Paint n Stuff | | Sico Paint / General Paint / DNR Coatings / Akzo Nobel? | | Solvents ? |
| | 0001194 | 635 MACKENZIE AVE SOUTH | Praxair / ICG Propane | | | | Active - Under Assessment |

Note: Sites with grey shade were not reviewed during this study.

**FIGURES**

**Figure #1 is missing from this document**

DWG. NUMBER: .../PROJECT/2360/CADD/2360-001.CDR

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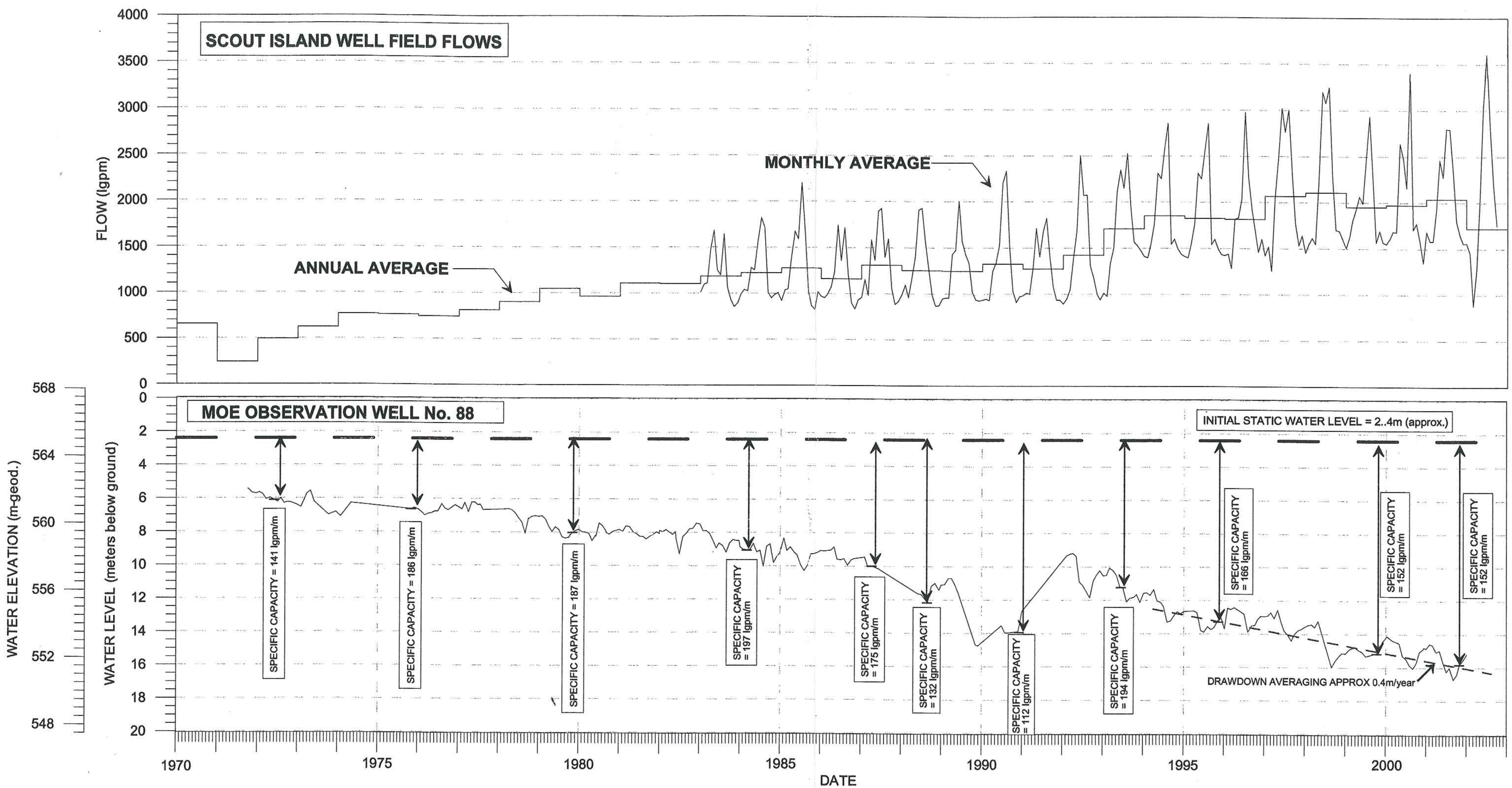
| | | | |
|---|---|---|---|
| DAYTON & KNIGHT LTD.<br>CITY OF WILLIAMS LAKE | PITEAU ASSOCIATES<br>GEOTECHNICAL AND HYDROGEOLOGICAL CONSULTANTS<br>VANCOUVER LIMA | | |
| HYDROGEOLOGICAL ASSESSMENT FOR WELL PROTECTION PLAN<br>SCOUT ISLAND WELL FIELD<br>WILLIAMS LAKE , B.C. | PLAN OF WELL PROTECTION PLAN STUDY AREA | BY: ATH/cz<br>APPROVED: | DATE: JUN. 03<br>FIG: 2 |

**Figure #3 is missing from this document**

**Figure #4 is missing from this document**

**Figure #5 is missing from this document**

# Figure #6 is missing from this document

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Note: Specific capacity is flow/drawdown, where flow is the average annual flow and drawdown is the difference between initial static level and current observation well #88 level

| | | | |
|---|---|---|---|
| HYDROGEOLOGICAL ASSESSMENT FOR WELL PROTECTION PLAN SCOUT ISLAND WELL FIELD WILLIAMS LAKE, BRITISH COLUMBIA | DRAWDOWN MONITORED AT WELL MOE88 AND CUMULATIVE WELL FIELD WITHDRAWL (1970 - 2002) | BY: PJG | DATE: JUN 03 |
| | | APPROVED: | FIG: 7 |

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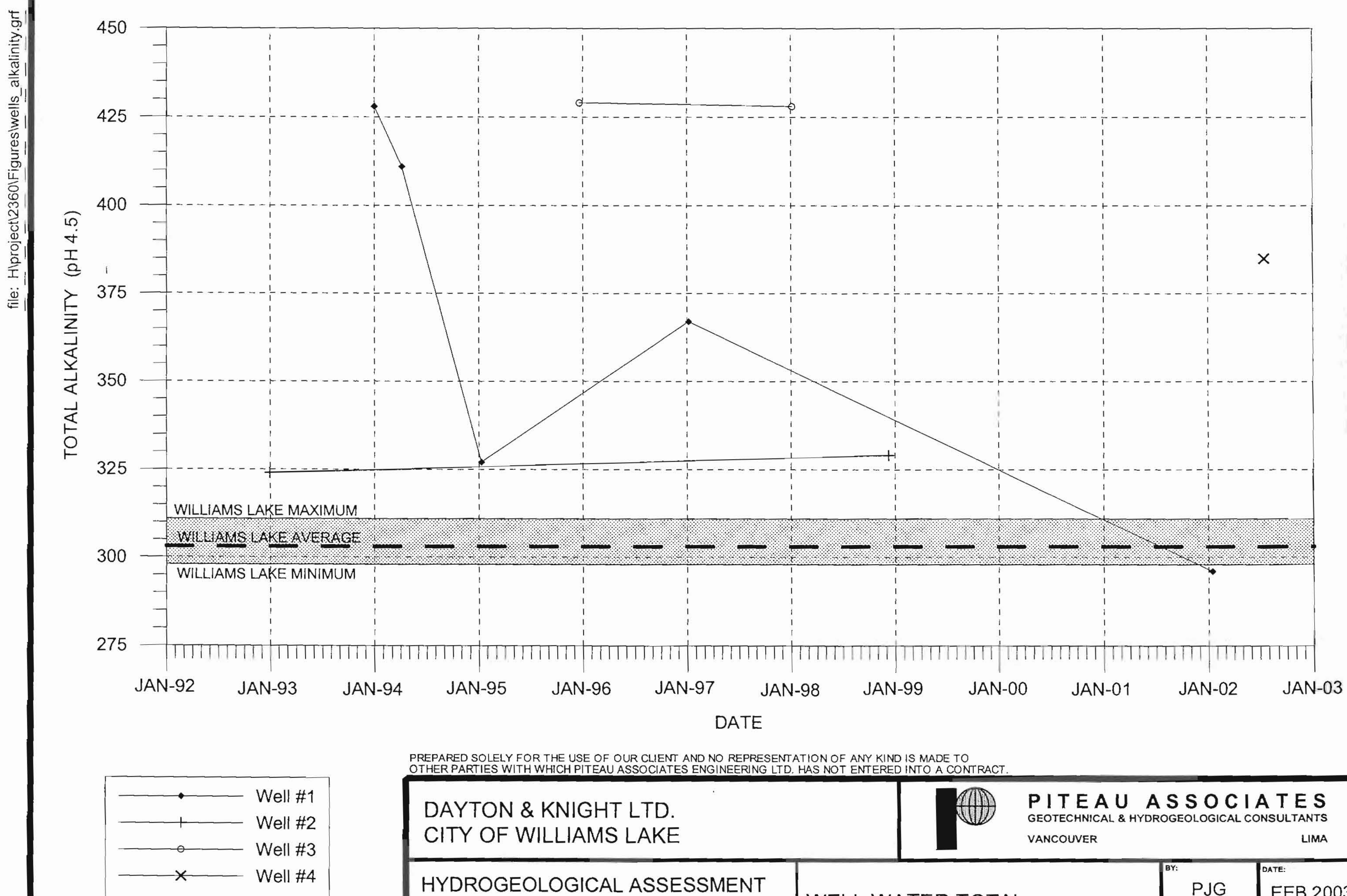
# APPENDIX A

# WELL WATER CHEMISTRY DATA PLOTS

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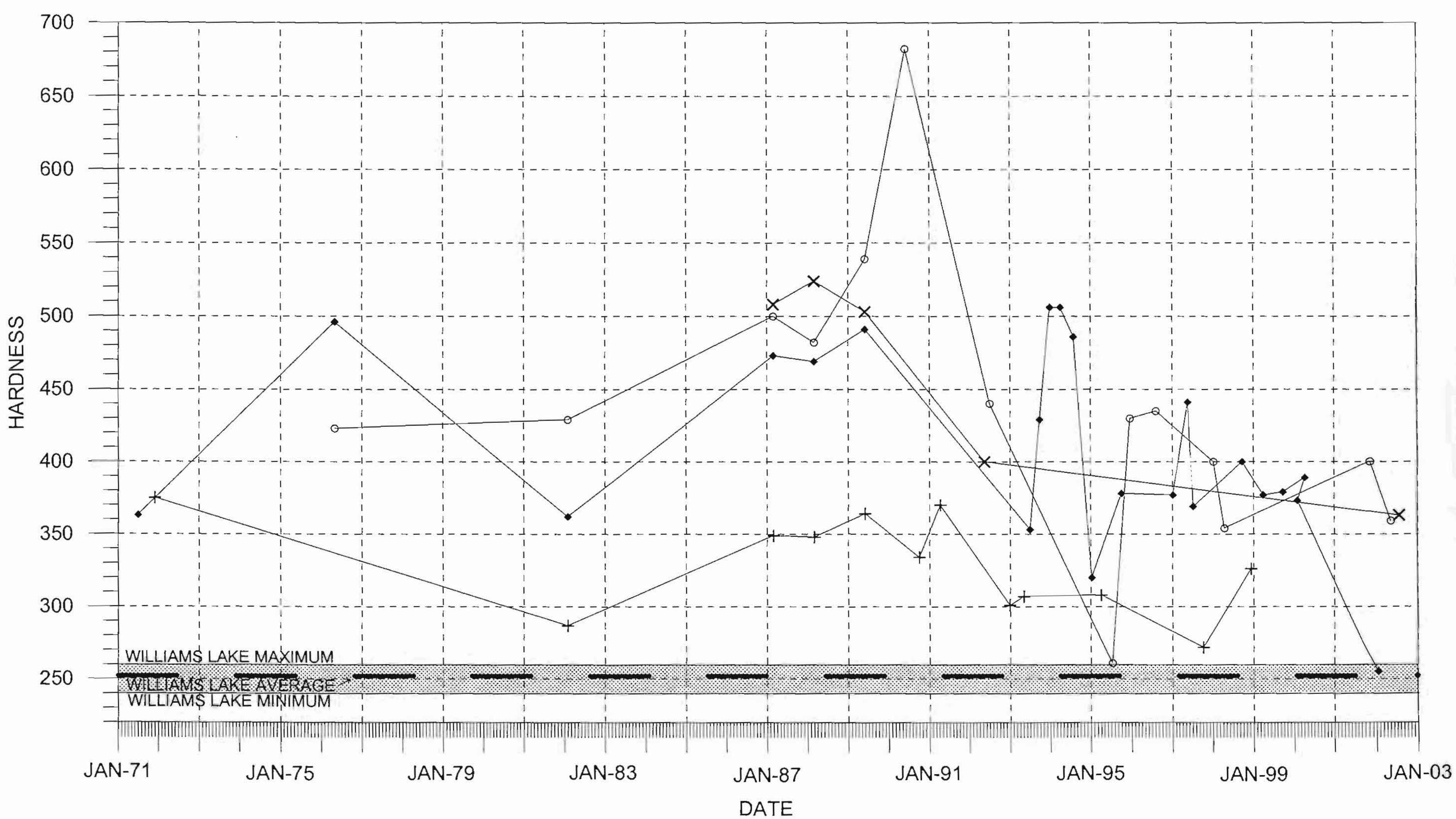
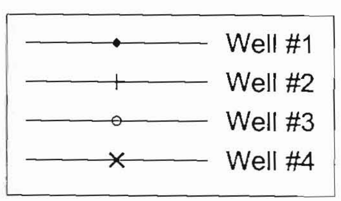
HYDROGEOLOGICAL ASSESSMENT
FOR WELL PROTECTION PLAN
SCOUT ISLAND WELL FIELD
WILLIAMS LAKE, B.C.

WELL WATER TOTAL
ALKALINITY VERSUS TIME

BY: PJG
DATE: FEB 2003
APPROVED: [signature]
FIG: A-1

file: H\project\2360\Figures\wells_hardness.grf



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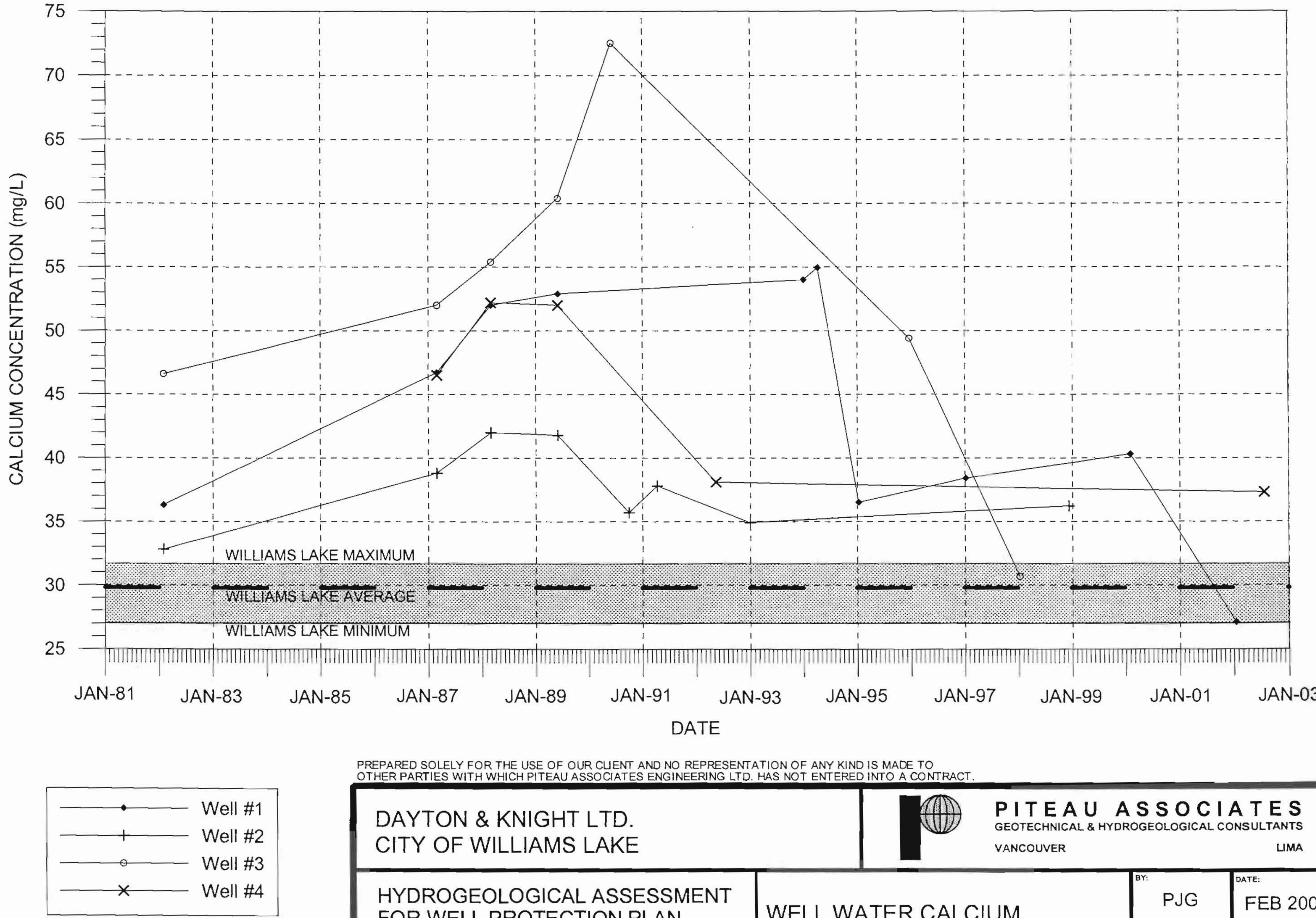
FOR WELL PROTECTION PLAN
SCOUT ISLAND WELL FIELD
WILLIAMS LAKE, B.C.

WELL WATER HARDNESS
VERSUS TIME

| BY: PJG | DATE: FEB 2003 |
|---|---|
| APPROVED: [signature] | FIG: A-2 |

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| | | | |
|---|---|---|---|
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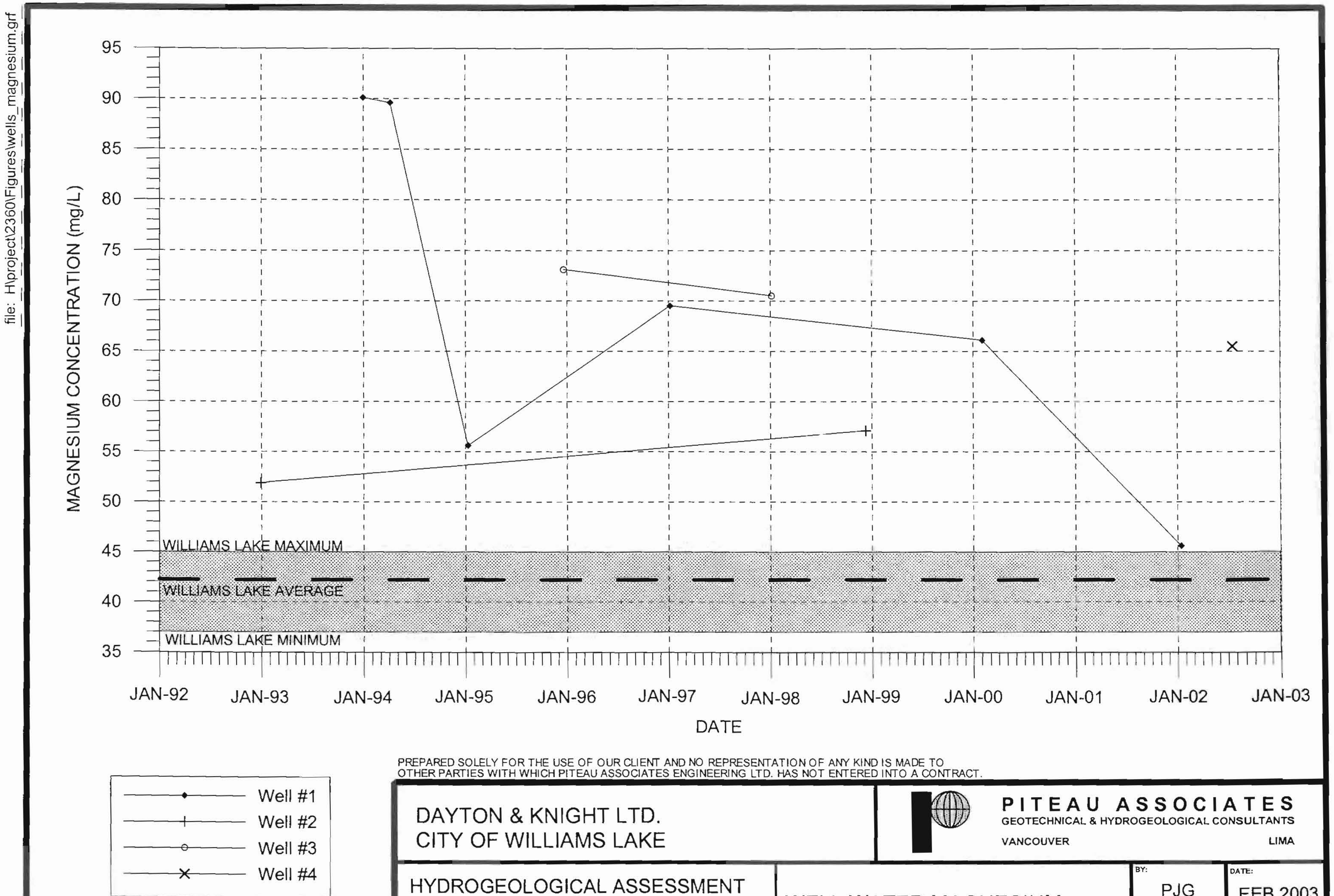
| HYDROGEOLOGICAL ASSESSMENT<br>FOR WELL PROTECTION PLAN<br>SCOUT ISLAND WELL FIELD<br>WILLIAMS LAKE, B.C. | WELL WATER CALCIUM<br>CONCENTRATION VERSUS TIME | BY: PJG<br>APPROVED: [signature] | DATE: FEB 2003<br>FIG: A-3 |

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WILLIAMS LAKE, B.C.

WELL WATER MAGNESIUM CONCENTRATION VERSUS TIME

BY: PJG
DATE: FEB 2003
APPROVED:
FIG: A-4

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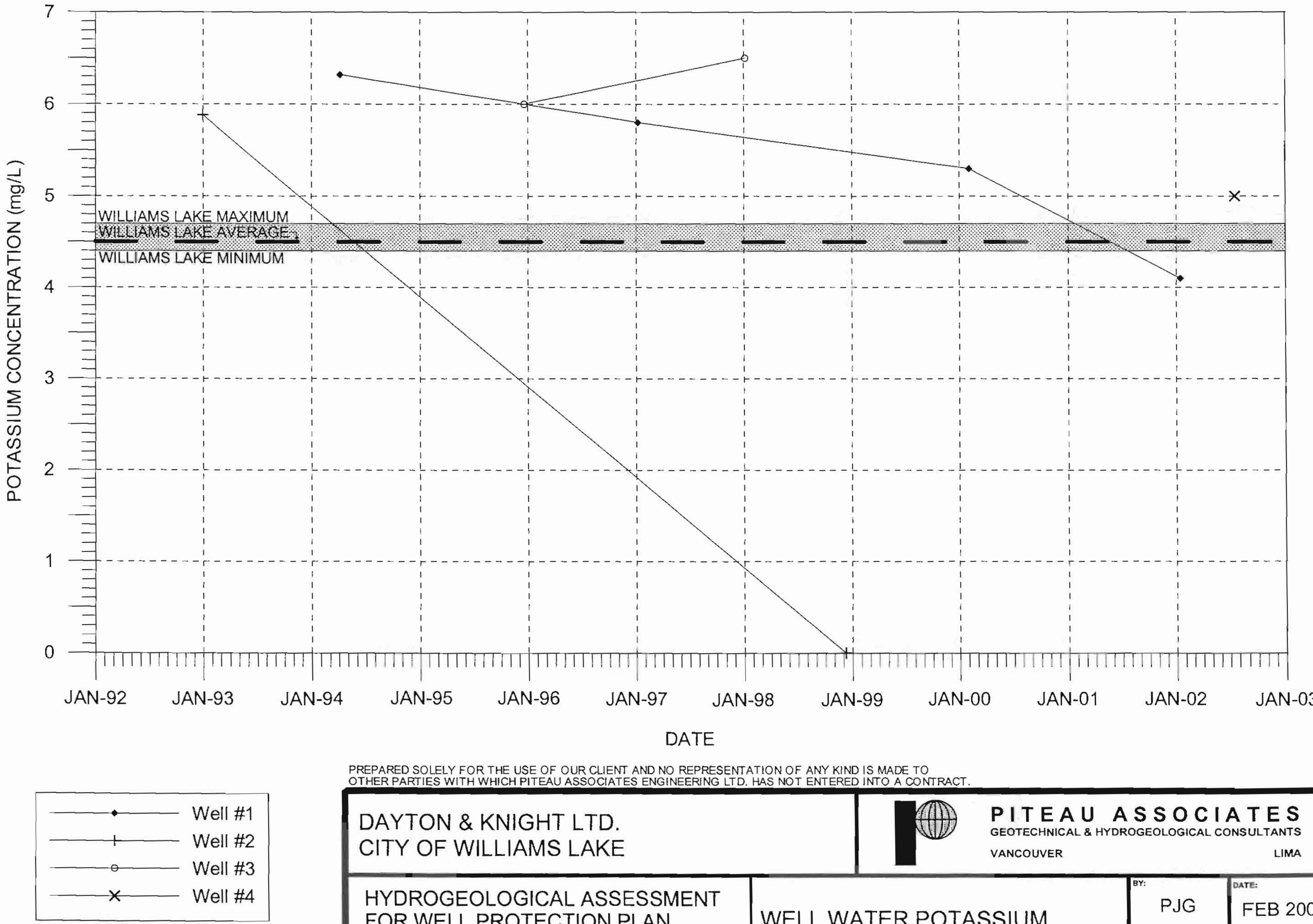


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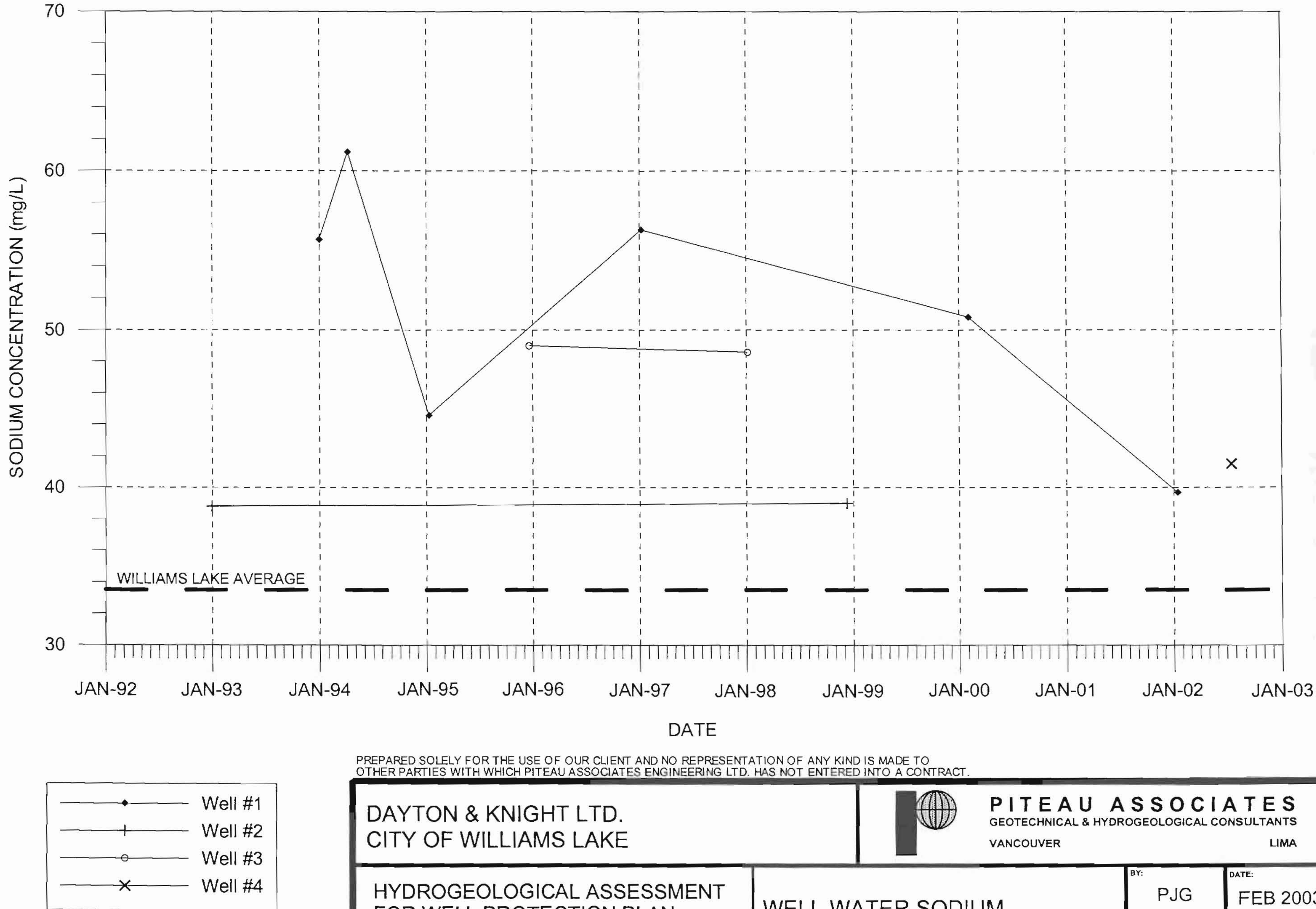
WELL WATER POTASSIUM
CONCENTRATION VERSUS TIME

BY: PJG
DATE: FEB 2003
APPROVED:
FIG: A-5

file: H:\project\2360\Figures\wells_sodium.grf



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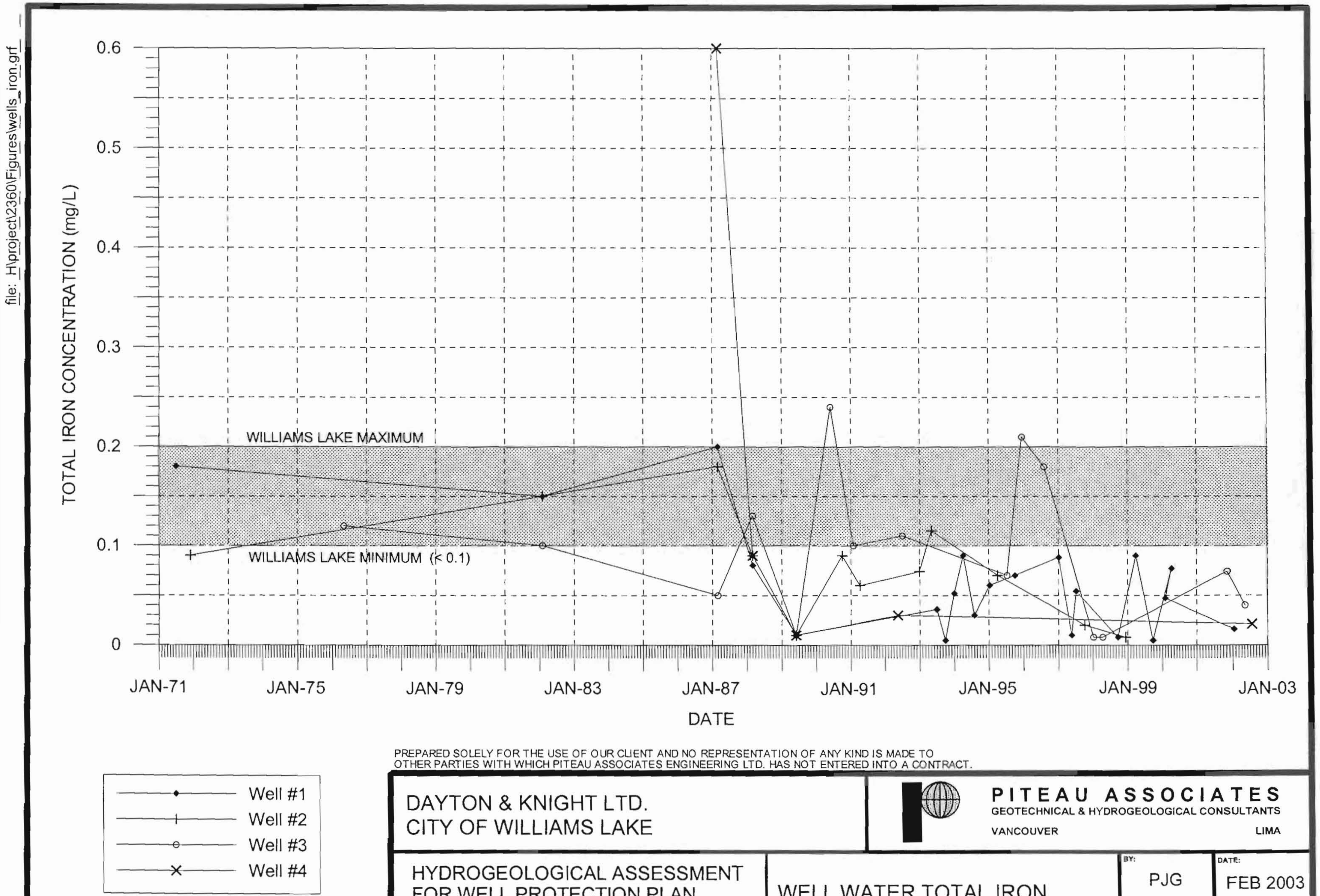
WILLIAMS LAKE, B.C.

WELL WATER SODIUM CONCENTRATION VERSUS TIME

BY: PJG
DATE: FEB 2003
APPROVED:
FIG: A-6

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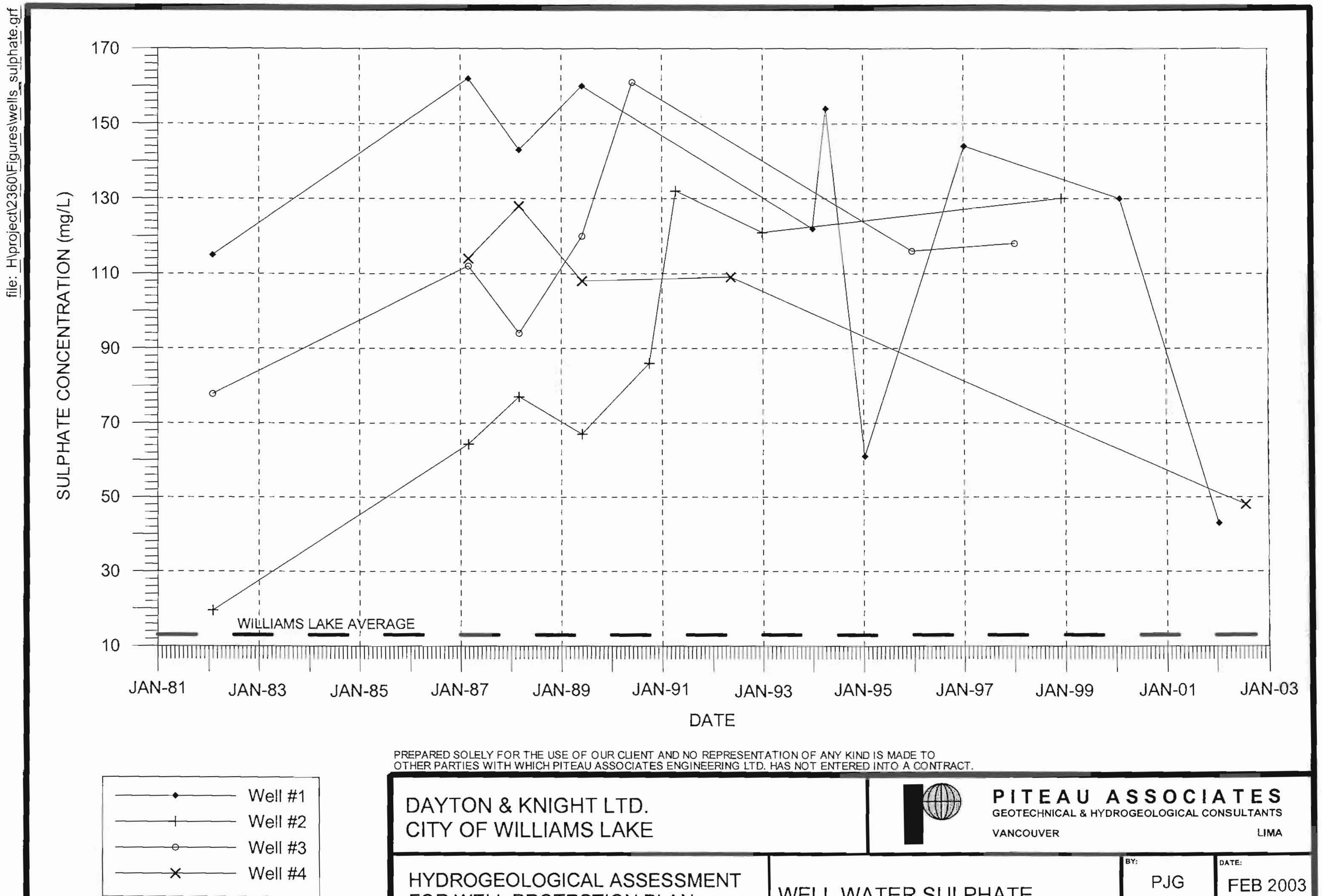
WILLIAMS LAKE, B.C.

WELL WATER TOTAL IRON CONCENTRATION VERSUS TIME

| BY: | DATE: |
|---|---|
| PJG | FEB 2003 |
| APPROVED: | FIG: A-7 |



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SCOUT ISLAND WELL FIELD
WILLIAMS LAKE, B.C.

WELL WATER SULPHATE CONCENTRATION VERSUS TIME

BY: PJG
DATE: FEB 2003
APPROVED:
FIG: A-8

# APPENDIX B

# NUMERICAL MODELLING

**TABLE B-1**
**SUMMARY OF CALIBRATED HYDRAULIC CONDUCTIVITIES**

| MODFLOW DATABASE # | DESCRIPTION OF MATERIAL | HYDRAULIC CONDUCTIVITY | |
|---|---|---|---|
| | | $K_{horizontal}$ (m/s) | $K_{vertical}$ (m/s) |
| 1 | Bedrock | $5x10^{-7}$ | $5x10^{-7}$ |
| 2 | Aquifer | $7x10^{-4}$ | $7x10^{-5}$ |
| 3 | Lake | 1 | 1 |
| 4 | Alluvium | $7x10^{-4}$ | $7x10^{-4}$ |
| 5 | Lake Bottom | $1.8x10^{-8}$ | $1.8x10^{-8}$ |
| 6 | Fine-grained Soils | $1.3x10^{-7}$ | $1.3x10^{-7}$ |

## TABLE B-2
## SUMMARY OF SIMULATED FLOWS IN FINITE-DIFFERENCE MODEL

| SCENARIO | RECHARGE | | TOTAL PUMPING RATE | WILLIAMS LAKE LEAKAGE | BACKFLOW TO WELLS | UPSTREAM METEORIC RECHARGE TO WELLS | WILLIAMS LAKE RIVER LEAKAGE | GROUNDWATER DISCHARGE TO WILLIAMS LAKE RIVER | GROUNDWATER DISCHARGE AT DOWNSTREAM MODEL BOUNDARY | SAN JOSE RIVER LEAKAGE |
|---|---|---|---|---|---|---|---|---|---|---|
| | mm/yr | Igpm | (Igpm) | (Igpm) | (Igpm) | (Igpm) | (Igpm) | (Igpm) | (Igpm) | (Igpm) |
| Oct 2000 | 17 | 632 | 1751 | 1126 | 533 | 92 | 1621 | 547 | 1142 | 59 |
| *Percentage of Total Pumping Rate* | | | | *64%* | *30%* | *5%* | | | | *3%* |
| 1988 | 17 | 632 | 1270 | 829 | 332 | 109 | 1527 | 629 | 1148 | 59 |
| *Percentage of Total Pumping Rate* | | | | *65%* | *26%* | *9%* | | | | *5%* |
| 1980 | 17 | 632 | 1000 | 667 | 229 | 104 | 1448 | 657 | 1150 | 60 |
| *Percentage of Total Pumping Rate* | | | | *67%* | *23%* | *10%* | | | | *6%* |
| Pre-Well Field | 17 | 632 | 0 | 87 | n/a | n/a | 1088 | 711 | 1154 | 57 |
| Future Demand | 17 | 632 | 2200 | 1383 | 597 | 220 | 1682 | 493 | 1136 | 59 |
| *Percentage of Total Pumping Rate* | | | | *63%* | *27%* | *10%* | | | | *3%* |

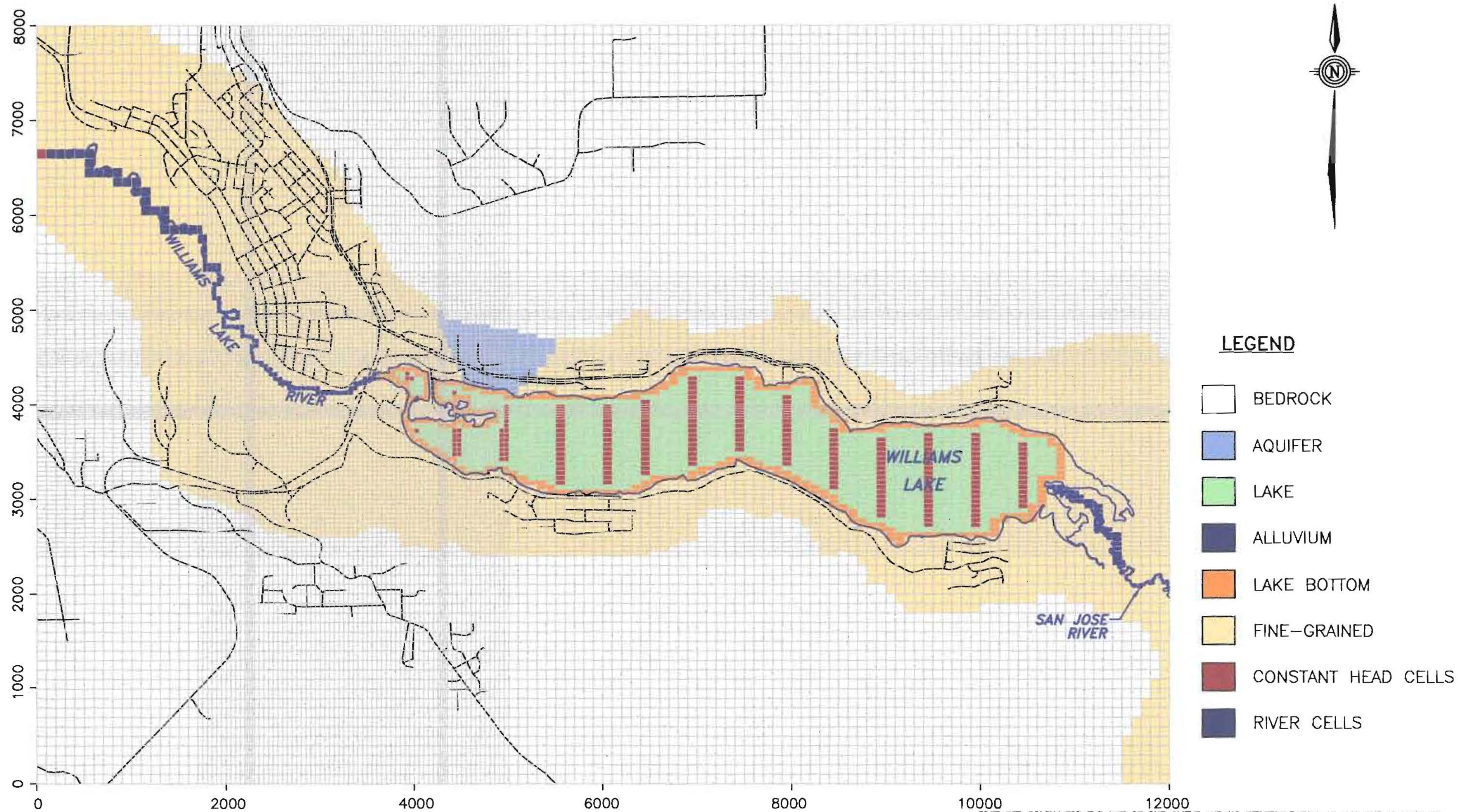
Notes:
1. The Future Demand scenario assumes that PW-5 will be pumping 210 Usgpm and the Scout Island wells are pumping at 2000 rates.

## TABLE B-3
## SUMMARY OF SIMULATED VERSUS OBSERVED GROUNDWATER ELEVATIONS

| SCENARIO | MOE WELL NO. 88 | | TW00-2 | | TW00-3 | | WLGCC WELL | |
|---|---|---|---|---|---|---|---|---|
| | OBSERVED | SIMULATED | OBSERVED | SIMULATED | OBSERVED | SIMULATED | OBSERVED | SIMULATED |
| Oct 2000 | 551.95 | 551.96 | 553.50 | 553.57 | 553.22 | 553.17 | *553.20* | 553.12 |
| 1988 | 557.50 | 555.90 | n/a | n/a | n/a | n/a | *556.90* | 555.13 |
| 1980 | 559.50 | 557.96 | n/a | n/a | n/a | n/a | *559.00* | 556.05 |
| Pre-Well-Field | *566.00* | 564.69 | *566.40* | 565.01 | *562.40* | 558.53 | *562.34* | 558.53 |
| Future Demand | n/a | 549.14 | n/a | 550.32 | n/a | 551.63 | n/a | 551.60 |

Notes:
1. See Fig. B-5 for a plot of simulated versus observed groundwater elevations for the 2000 scenario.
2. Italicized values are estimates and not actual observed groundwater elevations.
3. The future demand scenario assumes that PW-5 will be pumping 210 Usgpm and the Scout Island wells are pumping at average 2000 rates.

DWG. NUMBER: /PROJECT/2360/CADD/2360-002.DWG






0 1000 2000 3000m

SCALE 1:60000

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HYDROGEOLOGICAL ASSESSMENT FOR WELL PROTECTION PLAN
SCOUT ISLAND WELL FIELD
WILLIAMS LAKE, B.C.

PLAN OF FINITE-DIFFERENCE MODEL - LAYER 1

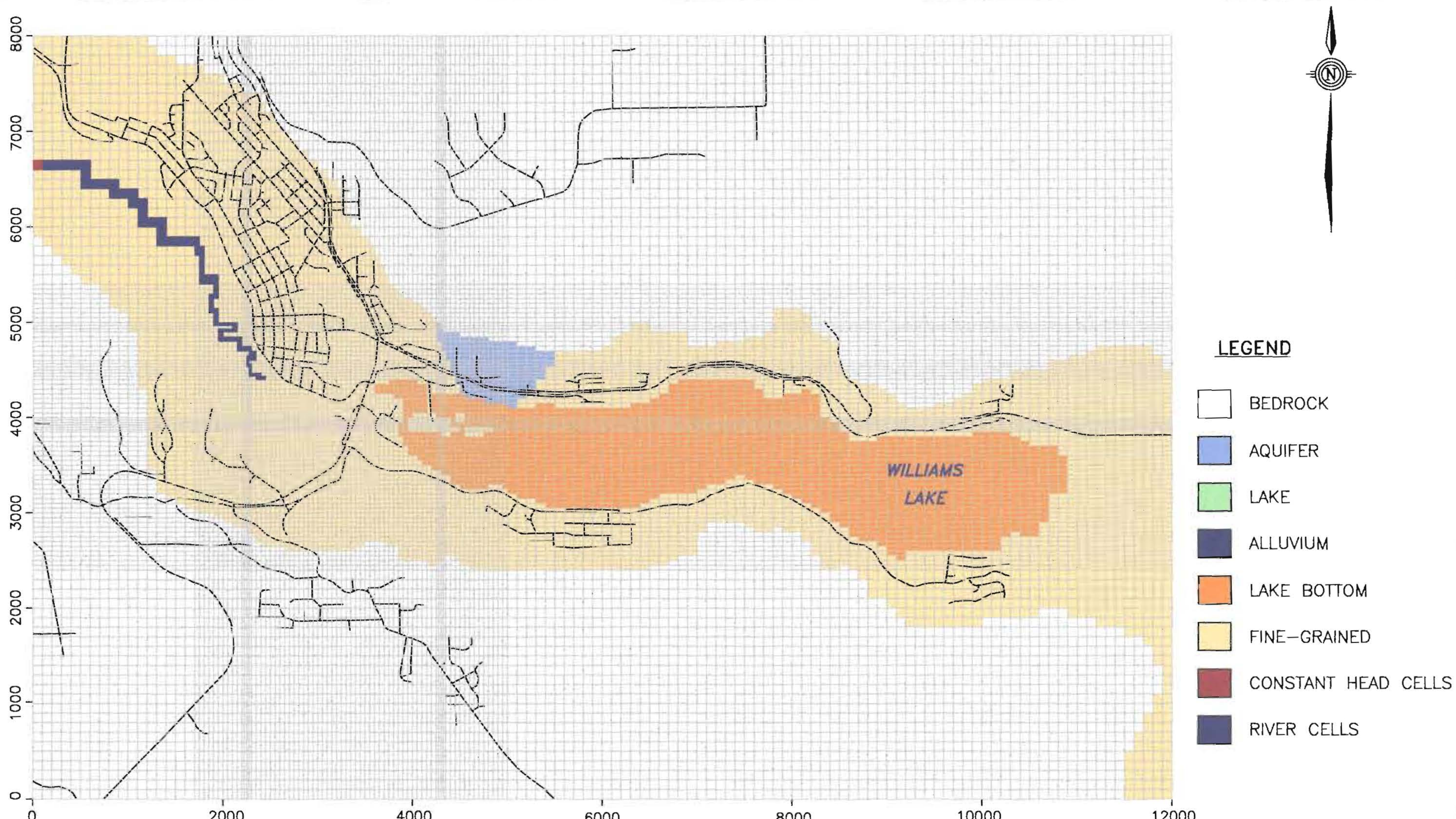
BY: MDP\ss

DATE: JUN. 03

APPROVED:

FIG: B-1

DWG. NUMBER: /PROJECT/2360/CADD/2360-003.DWG

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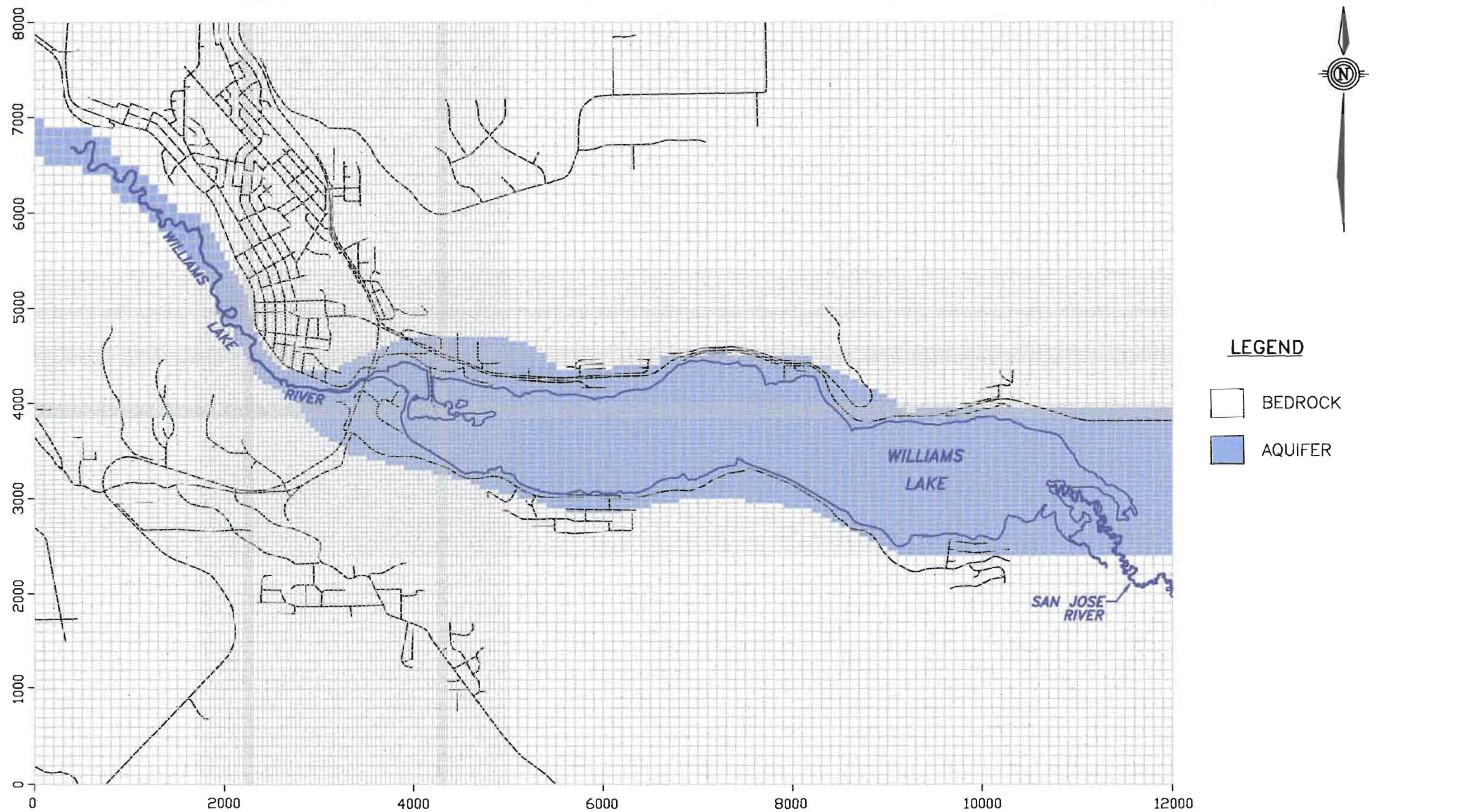
SCALE 1:60000

HYDROGEOLOGICAL ASSESSMENT FOR WELL PROTECTION PLAN SCOUT ISLAND WELL FIELD WILLIAMS LAKE, B.C.

PLAN OF FINITE-DIFFERENCE MODEL - LAYER 2

| BY: | DATE: |
|---|---|
| MDP\ss | JUN. 03 |
| APPROVED: | FIG: B-2 |

DWG. NUMBER: /PROJECT/2360/CADD/2360-004.DWG

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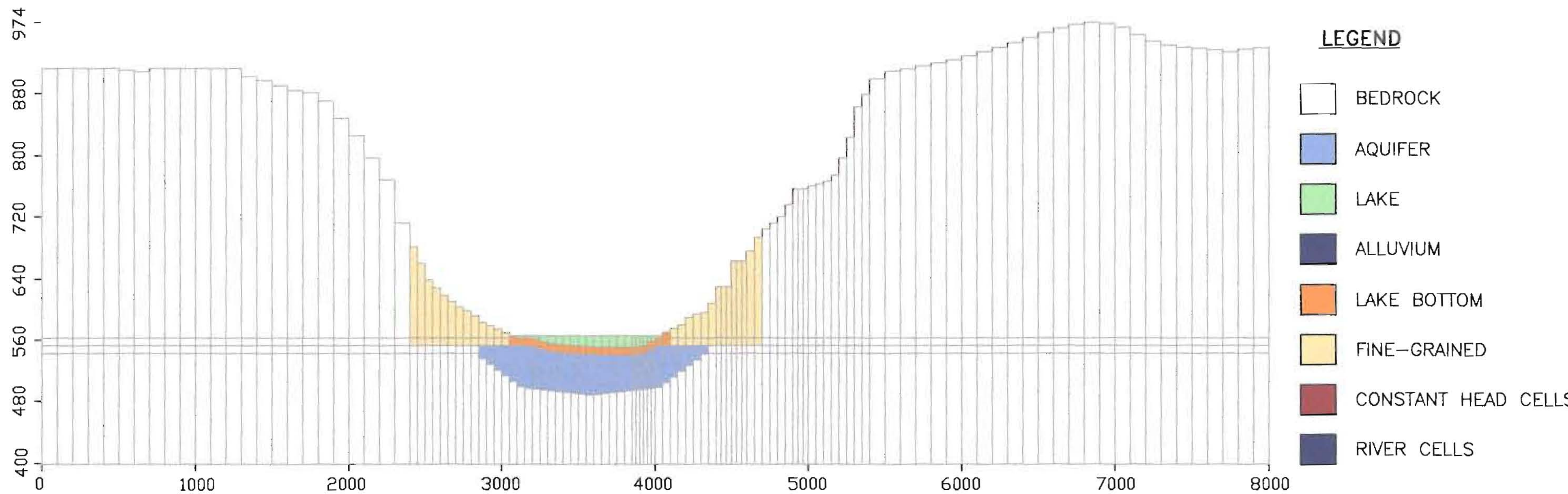
PLAN OF FINITE-DIFFERENCE MODEL - LAYER 3

| BY: | DATE: |
|---|---|
| MDP\ss | JUN. 03 |
| APPROVED: | FIG: B-3 |

DWG. NUMBER: /PROJECT/2360/CADD/2360-005.DWG



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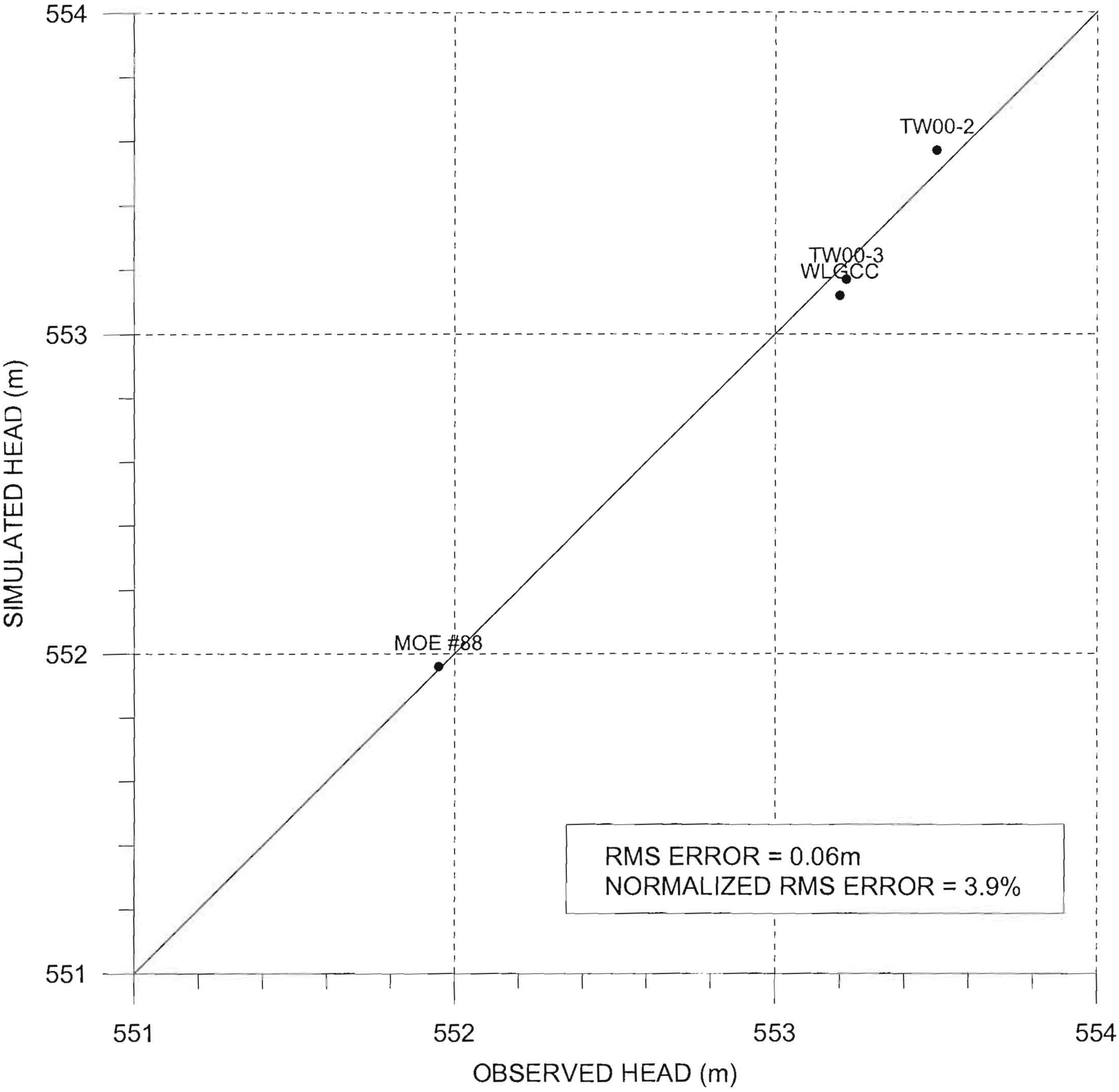
SCALE 1:40000

HYDROGEOLOGICAL ASSESSMENT
FOR WELL PROTECTION PLAN
SCOUT ISLAND WELL FIELD
WILLIAMS LAKE, B.C.

NORTH-SOUTH SECTION
THROUGH FINITE-DIFFERENCE
MODEL - 6000E

BY: MDP\ss
DATE: JUN. 03
APPROVED:
FIG: B-4




| | | | |
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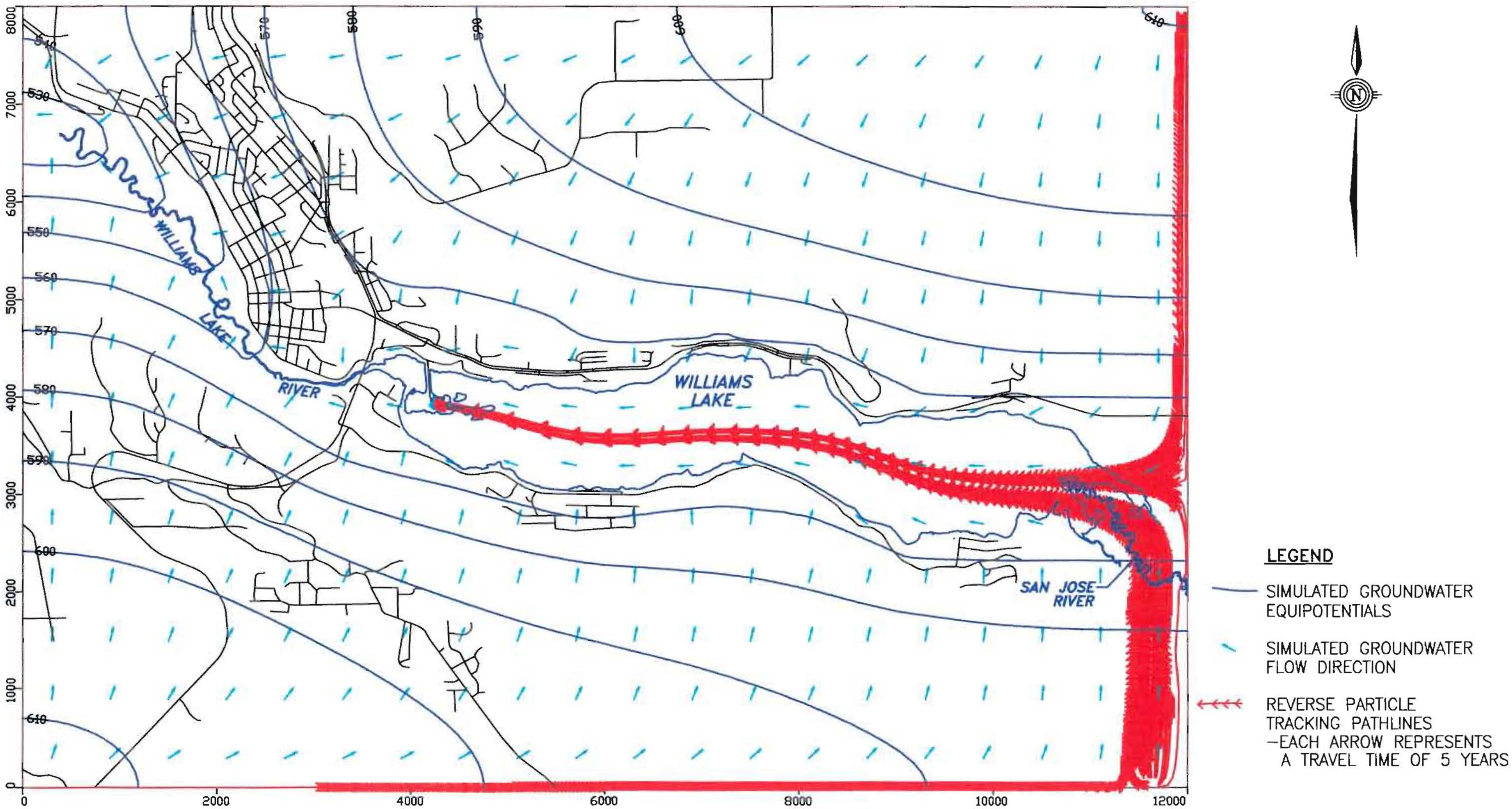
| HYDROGEOLOGICAL ASSESSMENT<br>FOR WELL PROTECTION PLAN<br>SCOUT ISLAND WELL FIELD<br>WILLIAMS LAKE, B.C. | CALCULATED VERSUS OBSERVED<br>GROUNDWATER ELEVATIONS FOR<br>OCTOBER 2000 BACK-ANALYSIS | BY: MDP<br>APPROVED: [signature] | DATE: JUN 03<br>FIG: B-5 |

DWG. NUMBER: /PROJECT/2360/CADD/2360-009.DWG



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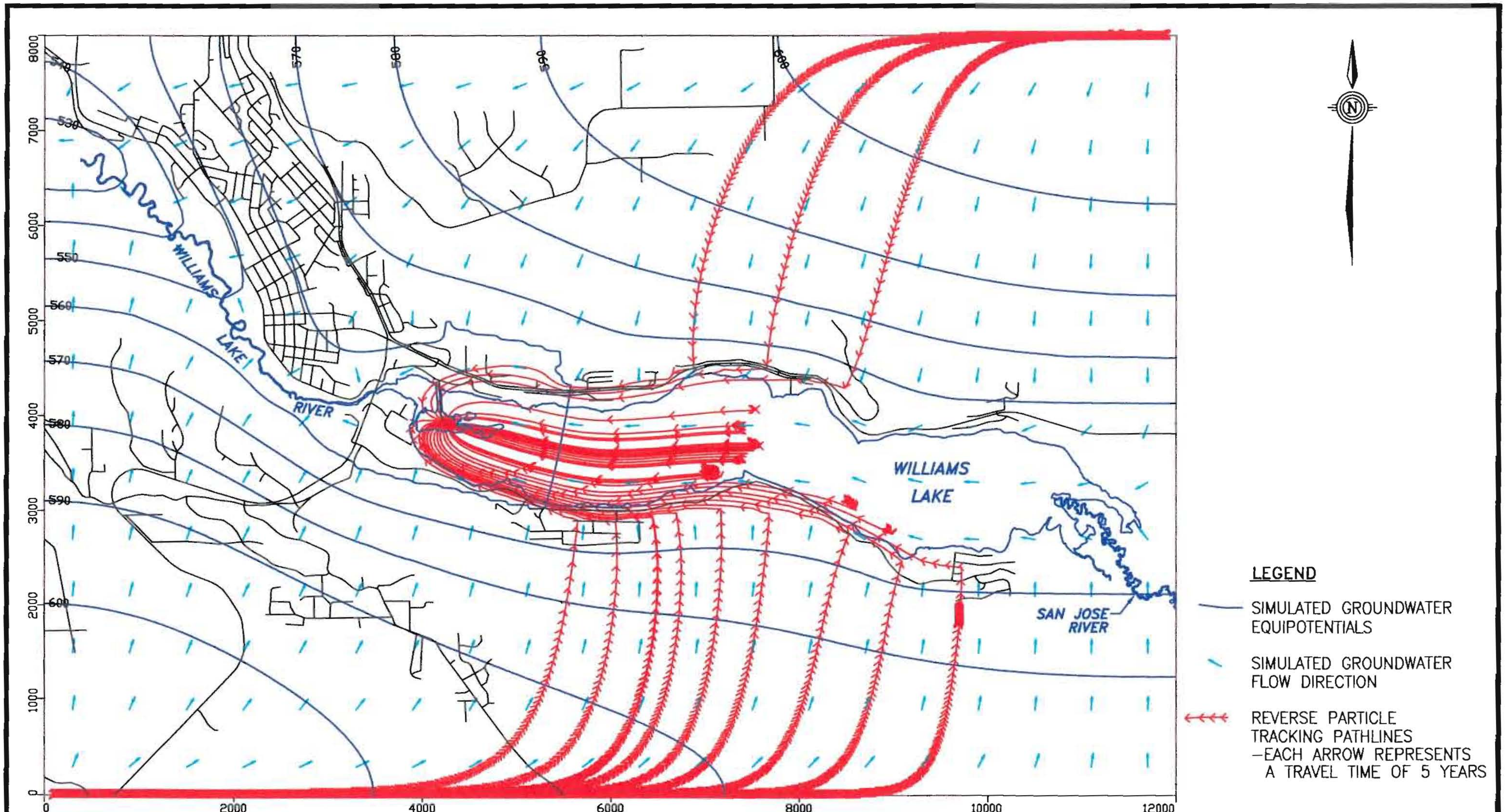
HYDROGEOLOGICAL ASSESSMENT FOR WELL PROTECTION PLAN SCOUT ISLAND WELL FIELD WILLIAMS LAKE, B.C.

STEADY-STATE SIMULATION RESULTS FOR PRE-1970 WITH NO PUMPING FROM SCOUT ISLAND

| BY: | DATE: |
|---|---|
| MDP\ss | JUN. 03 |
| APPROVED: | FIG: B-6 |

DWG. NUMBER: /PROJECT/2360/CADD/2360-008.DWG



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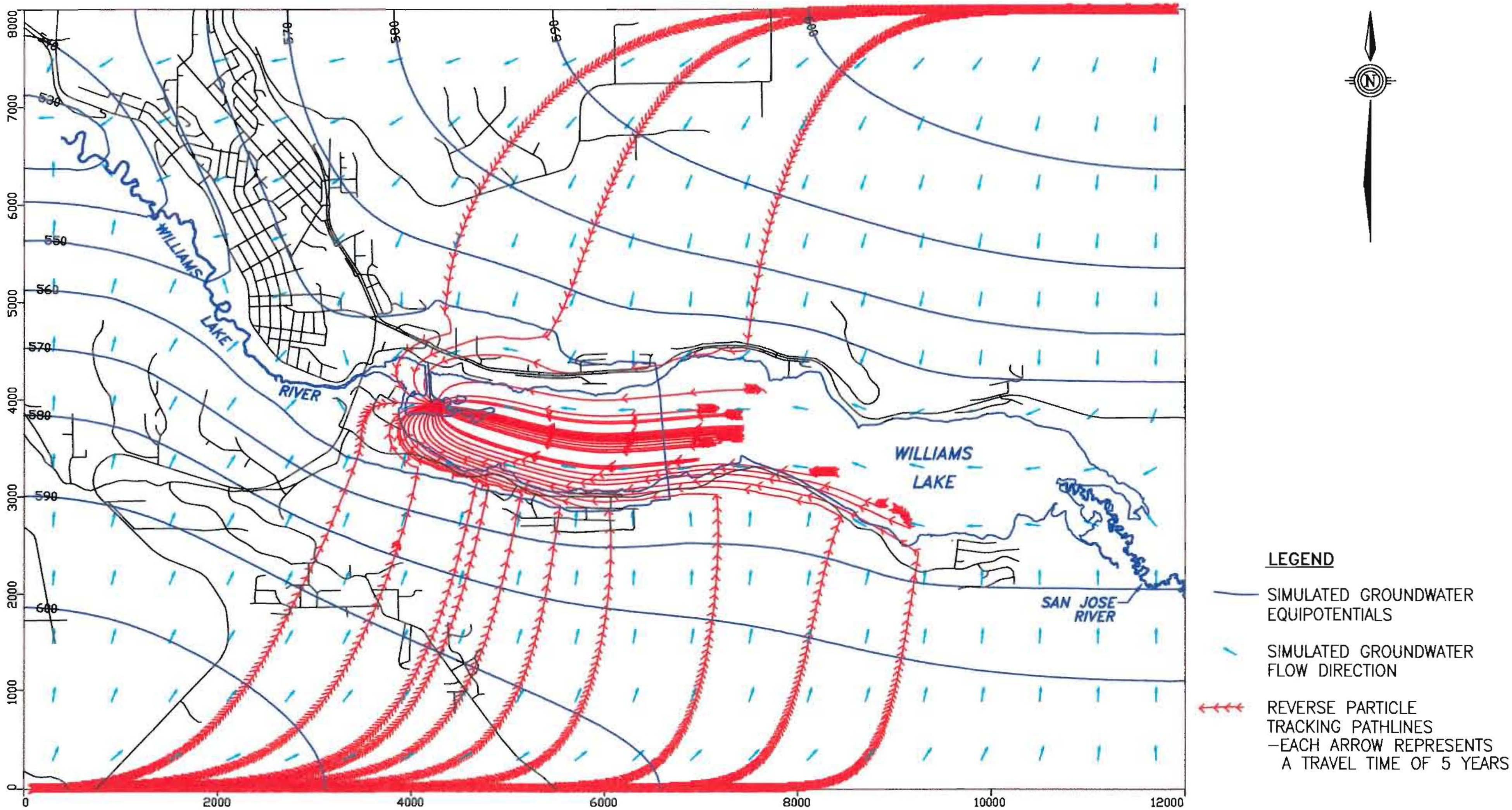
HYDROGEOLOGICAL ASSESSMENT FOR WELL PROTECTION PLAN
SCOUT ISLAND WELL FIELD
WILLIAMS LAKE, B.C.

STEADY-STATE CALIBRATION RESULTS FOR 1980 PUMPING RATES

| BY: | DATE: |
|---|---|
| MDP\ss | JUN. 03 |
| APPROVED: | FIG: B-7 |

DWG. NUMBER: /PROJECT/2360/CADD/2360-007.DWG

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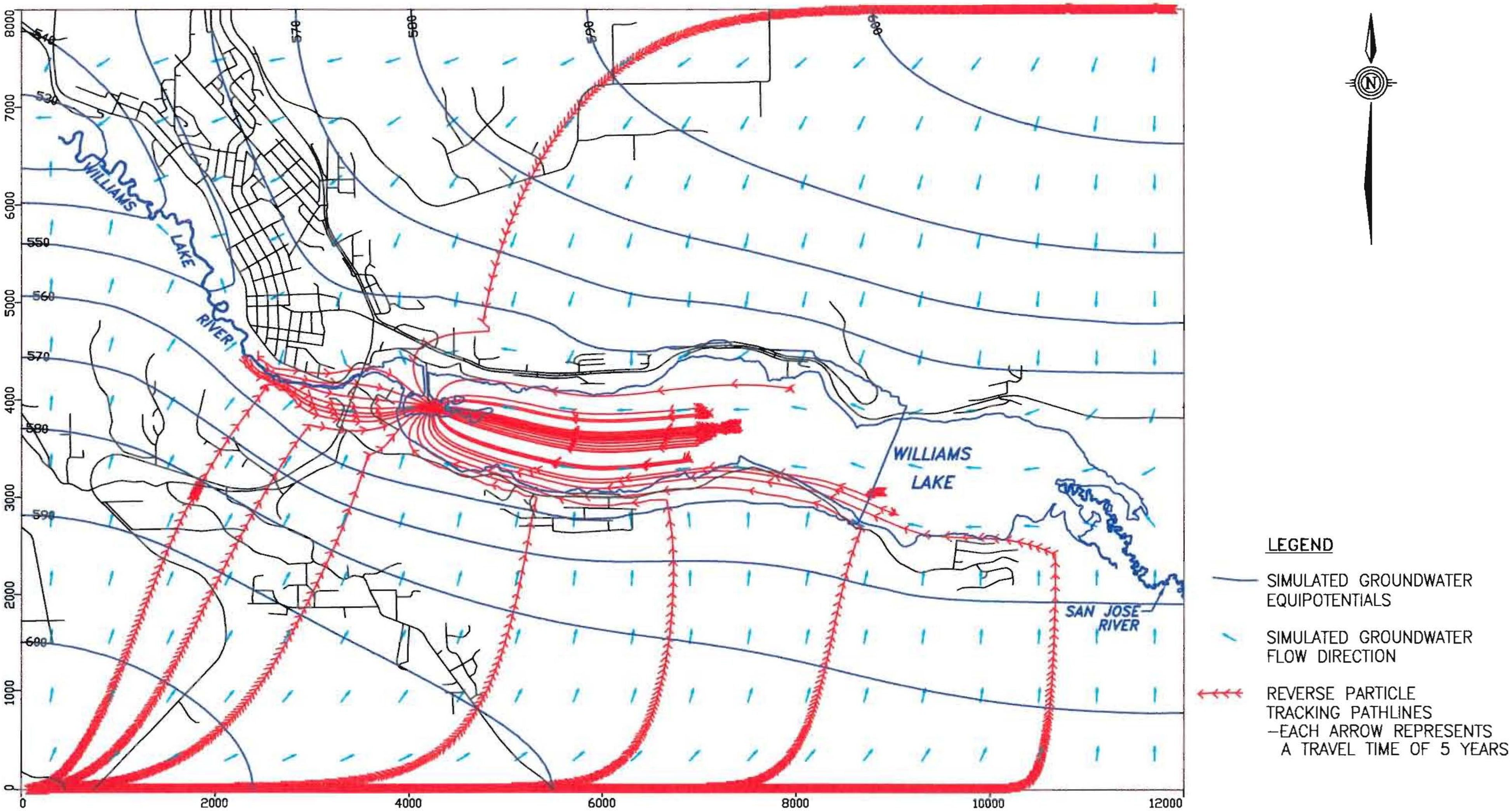
HYDROGEOLOGICAL ASSESSMENT FOR WELL PROTECTION PLAN SCOUT ISLAND WELL FIELD WILLIAMS LAKE, B.C.

STEADY-STATE CALIBRATION RESULTS FOR 1988 PUMPING RATES

BY: MDP\ss
DATE: JUN. 03
APPROVED:
FIG: B-8

DWG. NUMBER: /PROJECT/2360/CADD/2360-006.DWG

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STEADY-STATE CALIBRATION RESULTS FOR 2000 PUMPING RATES

| BY: | DATE: |
|---|---|
| MDP\ss | JUN. 03 |
| APPROVED: | FIG: B-9 |