S. Matthews

Okanagan Lake Water Level Management
Review of Past Trends
with Recommendations

FINAL REPORT

for:

Fisheries Section
Ministry of Environment, Lands and Parks
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by:

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EXECUTIVE **SUMMARY** **FINAL** REPORT

Management of water levels in the Okanagan Lake system and particularly Okanagan Lake itself is of great strategic importance to the Okanagan valley. **Irrigation/municipal** demands, flood reduction, fisheries habitat and spawning, and recreation uses all depend on how wisely the flow of water is managed. Control over the opening and closure of the outlet gates of Okanagan Lake at Penticton is crucial to determining lake levels and downstream flows.

Lake levels for **Okanagan** Lake presently set by Province of British Columbia were adopted in 1982, when the Okanagan Basin Implementation Agreement Report was **finalised**. Of particular importance are target water levels at key dates, such as February 1st and October 15''. Because of very large storage in Okanagan Lake in relation to discharge capability at Penticton, adjustment of lake levels takes several weeks of time. Procedures that will give operators more time and more flexibility in operating the lake are desired.

Presently the lake is operated most of the time at elevations that are higher than may be necessary. This creates problems for fisheries during high runoff years because of the need for extensive lowering of the lake during the winter months.

We have demonstrated a loose correlation between spring runoff conditions and global climate indicators measured the previous summer. In 13 out of 66 years when the 6 month **SOI** (Southern Oscillation Index) is less than -0.6, the May-June inflow volume to Okanagan Lake was no larger than 33% above normal. Only in one year (1983) was there an exception, otherwise there were **no events** during these years that were **significant** floods. Three of these, 13 years were the most serious drought years of record. This means that a climate situation causing normal or drought conditions in lake inflows the following **spring** *can* be foreseen, and plans to keep the lake level higher than in the majority of years can be initiated on 1st September. Adjustments to the outflow at Penticton ***can*** be started at this time, and the decision about the target water surface elevation **confirmed** on **30th** September.

With long range weather trend predictions **improving,** we believe that it may be possible to operate the lake during the winter at lower elevations than previously used, without increasing the **risk** to irrigation water supplies. This leads to the idea of utilizing:

1). a revised water **surface** target for **01** February, such as 1120.7 feet (341.6 m), 0.15 m less than presently used, with a similar revision to the water **surface** target for 15'' October. These water surface elevation values would be used for the majority of years.

2). The same water surface target as used at present on 01 February (341.75 m) for low **SOI** years only.

In planning for implementation of this idea, some important checks should be undertaken to see if it is feasible. Water flow and water balance studies using the historic data set should be carried out to check on the following points:

*A). Proposed lower water **surface** elevations during the majority of **years:***

- Would the additional amount of water that will be released during late **summer/fall** imply flows at Oliver gauging station in excess of 28.3 **m^3/s** (see presently allowed flows, page 10).
- Would there be sufficient water in storage to supply the normal **winter/spring** minimum release flows (3 **m^3/s**) from Okanagan Lake.
- Would the lake be able to fill during **spring/summer** the majority of years, following winters when the revised target is used.

B). Allowed flows at Oliver gauging station: Are the presently allowed flows during the period August **1st** to October 31**st** unnecessarily conservative. Would it be possible to release up to 45 m^3/s (for example) during this period.

C). Lower lake levels: Would the proposed revised range of lake levels cause problems with dock owners (fixed elevation docks).

Part of a **future** procedure, if feasible, will involve River Forecast Centre, Ministry of Environment, Lands and Parks carrying out an assessment of the previous 4-6 months **SOI** value prior to August 31st **year. Other global indicators of heat and weather in the Pacific** Ocean may be available and **may** be preferable predictors (better than **SOI** value) of seasonal **runoff**. These indicators should be tested for correlation with Okanagan basin **runoff**. Yearly recommendations should be made for the Okanagan system, if runoff conditions for the following spring are likely to be significantly larger than, or significantly smaller than average. Adjustments to lake outflows to be started by Water Management **staff** on 1' September of each year, to allow water level to meet target levels on **15th** October and 1st **February.** Confirmation of the decision on the target water level should be made on 30'' September.

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FINAL REPORT

1.0 Introduction

Water supplies in the Okanagan basin are controlled mainly by inflows and outflows fiom Okanagan lake. This is a large lake with relatively small average throughflow. Hydrologically the area is arid, with low annual runoff amounts, and large interannual fluctuations in runoff In addition, the evaporation from Okanagan lake is large, so the outflow in wet years vastly exceeds the outflow in dry years. A map of the area is shown (Figure 1), with the downstream river (Okanagan river), leading via Skaha, Vaseau and Osoyoos Lakes to the US border, and fiom there to the confluence with the Similkameen river. The Okanogan river (as it is called in Washington state) joins the Columbia River about 100 km south of the international border.

The capacity of the channelized Okanagan river downstream of Okanagan lake is not large. The peak flow that it can pass depends on factors such as the backwater exerted by Skaha Lake, and by tributary creeks. The design flow of the channelized river is 60 m^3/s. Under optimal conditions higher flows can be released (for example during the early part of August 1997, a flow estimated at about 77 m^3/s was passed). Prolonged release of high flows sometimes causes damage to drop structures in the river downstream of Skaha Lake. The maximum daily volume (about 7.5 million m^3) that may be released fiom Okanagan Lake at this flow rate is a small fraction (1.8%) of the live storage volume of the lake. Thus many days and weeks of outflows are needed to significantly change the water surface level of the lake.

Water supply management, water quality and related issues for Okanagan Lake were comprehensively investigated in 1972-3, and in 1974 a series of reports which included the *Comprehensive* Framework *Plan* were published. A summary of selected recommendations fiom this report is included as Section 3.0 of the present report. The Plan emphasized aspects such as flood reduction, water supply for irrigation and municipal use, phosphate reduction fiom treated sewage waters, and flow needs for Okanagan river sockeye salmon. A clause was inserted in regard to shore spawning kokanee and regulation of lake levels.

Engineering and other work set out in the Plan was executed, and a report was published at the end of the implementation period (September 1982). The report was titled Report on the *Okanagan* Basin Implementation Agreement, and included details of the management of lake surface levels. Recommendations were made specifically directed at mitigating the effects of man made water surface changes in lake levels on shore spawning kokanee populations.

For the last 15 years the lake has been operated by Water Management Branch staff, following the guidelines set out in the Plan, and in the Implementation Report. The Plan permits late winter **drawdown** of the lake, if needed, to create storage for larger than average anticipated runoff events the next spring and summer.

This procedure has the following attributes:

1. ***Benefit*** in creating space in the reservoir so that high runoff flows appearing weeks or months later can be stored and slowly released. This reduces maximum water surface levels the following summer, and reduces summer flow peaks in the Okanagan river also. Lake-side residents, particularly those with low basements, benefit fiom reduced flood levels, because inundation of basements is **minimized.**

2. *Detriment* for lake and riverine spawning fish, because a). the lake may be drawn down sufficiently that lake spawning kokanee eggs may be **left** high and dry prior to completion of incubation and hatching, and because b). high flows in the Okanagan River during the winter months may mobilize gravels and cause wash out of sockeye salmon spawning sites. In this context, both the sockeye salmon run on the Okanagan River and the Okanagan Lake kokanee population are particularly valuable. The sockeye salmon run is one of only two substantial runs left on the Columbia River system, and the Okanagan Lake kokanee are unique, and very different in spawning **behaviour** and habitat fiom other salmon stock. They thus have a high value fiom the point of view of genetic diversity.

Difficulties in managing the system fiom the point of view of fish spawning and survival stem fiom the large lead time involved. The fish (both lake and riverine **salmonids)** spawn during the month of October, and select sites based on water levels (in the river and the lake) that they see at this time. These water levels need to be kept within a **fairly** close band of the level at spawning time (sometime in mid or late October) to ensure optimum survival. Water levels must be maintained until early or mid April for the kokanee **alevins** to mature **successfully**. If these levels are held, and an **unusually** high snow pack year occurs (as in the 1996-97 winter), there is insufficient time during the April to early May period to create storage space in the reservoir prior to the onset of flooding. The result is very high lake levels and flooding of homes and other **facilities** around the lake. Although the flood construction level has been set at a relatively high elevation (343.66 m) for many years, there are a lot of non-conforming residences and other properties. If the levels in Okanagan Lake are lowered starting in late January (as was done in **1997),** then it is possible to create sufficient storage to reduce flooding in the summer months. However this is done to the detriment of lake spawning kokanee stocks.

In the natural system, with uncontrolled flow over a gravel or cobble bar at the outlet of Okanagan

Lake (see Figure 2), the changes in outflow were slow and determined by slowly changing lake levels as the winter months progressed. No provision was possible to reduce peak water elevations during the summer, by pre-releasing water following large snow fall winters. With the installation of a sill and gates at the outlet (starting in 1915), the possibility has existed for the last eighty years of significant lowering ("pulling the plug") of the lake, below previously occurring natural lows. This is done during high snow pack winters, to create room for storage of anticipated flood events.

2.0 Available Hydrological Data

Large amounts of hydrological data have been collected for Okanagan Lake and the Okanagan river system. A listing of a selection of the most important types of data for water level management is listed in Table 1. Water licence information is obtained fiom the Water Rights Information System computer files, at Water Management Branch, MEL&P. Meteorological and hydrological information is obtained fiom Environmental Services and Information Division, Environment Canada.

3.0 Okanagan Basin Framework Plan & Okanagan Basin Implementation Agreement

Two important sets of documents were produced, detailing what engineering, construction and administrative work had to be done, and how to operate Okanagan Lake and its tributaries. These were the report on the Canada-British Columbia Okanagan Basin Agreement, 1974 and the report on the Okanagan Basin Implementation Agreement, 1982. The first of these sets of documents included a comprehensive framework plan, referred to as the Plan. Recommendations fiom these documents were incorporated into the Water Management Branch's operating schedule, which specifies target lake levels and river flows at different times of the year.

A. *The* Plan: A comprehensive analysis of the situation with water supply, flood potential and eutrophication possibilities for Okanagan Lake was carried out in the early seventies. Under a joint Federal-Provincial effort, a Canada British Columbia Consultative Board was set up to oversee the work that had been funded in October 1969 under the Okanagan Basin Agreement. This work culminated in a report, published in 1974 in three parts:

- Summary Report, including the Comprehensive Framework Plan: Canada British Columbia Okanagan Basin Agreement, March 1974, 42pp.
- Main Report: Canada British Columbia Okanagan Basin Agreement, March 1974,536 pp.
- Twelve Technical Supplement Reports, including Volume 1: Water Quantity Report: Canada British Columbia Okanagan Basin Agreement, March 1974, 610 pp.

The study analyzed three growth projections for the period 1970 to 2020. With the highest growth projection (2.6% per annum) of the three, the report concluded that there was sufficient water in the basin to supply all projected withdrawals and to meet proposed fishery and recreation requirements.

TABLE 1

Summary of Hydro meteorological Data for Okanagan Lake

Type of data	Sampling period	Years available
Evaporation:		
Kelowna Airport	Monthly	1971 to present
Penticton Airport	Monthly	1951-1980
Summerland	Monthly	1962-1992
Precipitation:		
Kelowna Airport	Monthly	1971 to present
Penticton Airport	Monthly	1951 to present
Water Surface levels:		
Okanagan Lake at Kelowna	Daily	1943 to present
Okanagan Lake at Penticton	Daily	1920-1974
Stream flow on Okanagan River:		
Okanagan River near Oliver	Daily	1944 to present
Okanagan River at Penticton	Daily	1921 to present
Okanagan River at Okanagan Falls	Daily	1915 to present
Okanagan River at Oroville	Daily	1942 to present
Stream Flow in main tributaries which supply 60% of the inflow to Okanagan Lake:		
Mission Creek near East Kelowna	Daily	1949 to present
Vernon Creek at outlet of Kalamalka Lake	Daily	1927 to present
Trout Creek at the mouth	Daily	19691982
Penticton Creek above Dennis Creek	Daily	1970 to present
Equesis Creek near the mouth	Daily	19691982
Kelowna Creek near Kelowna	Daily	1922 to present
Powers Creek at the mouth	Daily	19691982
Peachland Creek at the mouth	Daily	19691982
Water Licences:		
919 licences leading to a total licenced diversion of 110 Mm^3 annually.		

This assumed the withdrawal of larger volumes of water from Okanagan Lake during prolonged drought periods than had occurred in the past. Also forecast was the need for additional headwater storage of water.

Forecast ranges of Okanagan Lake water surf' levels were as follows:

> *Not normally to exceed four feet in any one year, but a total variation of nine feet may occur between an extreme flood level in one year, and an extreme low lake level following a succession of drought years.*

The projected maximum elevation of Okanagan Lake during a 200 year flood event was 1125.5 feet (343.05 m). This maximum elevation was based on statistical projections, and is hard to interpret and use, because the maximum levels attained in Okanagan Lake depend on inflows and how the outflow gates are regulated during the weeks and months leading up to the major flood event.

In the Section concerning "Detailed Recommendations", "Part A Water Quantity", water levels in Okanagan Lake are recommended to be regulated to target values (see Table 2). Target water surface elevations for Okanagan Lake and sill elevations at the lake outlet are summarized on a scale drawing (see Figure 4). Values shown in Figure 4 are as mentioned in the Plan, and as mentioned in the Report on the Implementation Agreement.

Table 2. Target Water Surface Elevations for Okanagan Lake Recommended in the Plan (1974)

Normal Operating Conditions:	Regulated within its normal four foot range (1119.8 to 1123.8 feet, 341.32 to 342.54 m) in all years except extreme flood years (inflows projected to exceed 500,000 acre feet/yr, 617 million m^3/yr) and successive drought years (inflows less than 200,000 acre feet/yr, 247 million m^3/yr).
Flood Conditions Predicted:	Lake to be drawn down below its normal low water elevation of 1119.8* feet (341.32 m) prior to freshet by up to one foot (0.305 m). (Draw down to as low as 341.01 m is thus recommended, if necessary).
Drought Conditions Predicted:	Maintain the lake level as high as possible. Under prolonged drought conditions, the lake level may reach as low as 1116.8 feet (340.4 m). The bottom 0.92 m of water storage is known as 'emergency storage".

*Normal low water elevation specified in Plan of 341.32 m. Note that operational experience has shown that in most years meeting this target would result in excessive and unnecessary drawdown. In practice, a minimum level in an average year of **341.5** to **341.6** m is usually sufficient.

Recommendations are also made in the Plan, as follows:

- Flood plain zoning be implemented and enforced by a regional water management authority up to **1127.5** feet **(343.66** m) elevation around Okanagan Lake. Further development on this floodplain should be limited to recreation, parks and agriculture

- Irrigation and domestic intakes around Okanagan Lake be adjusted as required to be **operable** at a minimum lake elevation of **1116.8** feet **(340.4** m)

- As **of March 1974**, future intakes, wharves, boat ramps and other structures around Okanagan Lake be built to operate with a lake elevation range of **1116.8** to **1125.5** feet **(340.4 to 343.05** m). .

- Water requirements for sockeye salmon in Okanagan River should be met in **all** years, except consecutive drought years, using the following guidelines:

DATES	**FLOWS**, OLIVER GAUGING STATION
August **1** to September **15**	**300 - 450** ft^3/s (**8.5 - 11.3** m^3/s)
September **16** to October **31**	**350 - 550** ft^3/s (**9.9** to **15.6** m^3/s)
November **01 -** April **30**	**175 - 1000** ft^3/s (**5.0 - 28.3** m^3/s)

"In two or more consecutive drought years, these flows may have to be reduced".

NOTE THAT THESE NUMBERS ARE FROM TECHNICAL SUPPLEMENT IX. **THE** NUMBERS SHOWN IN **MAIN** AND SUMMARY REPORTS ARE **WRONGLY** REPRODUCED.

- Clause **40:** That due consideration be given to shore spawning kokanee when regulating Okanagan **Lake** water levels over the winter months. To **minimize** damage to shore spawning kokanee during the fall and winter months, the **drawdown** of Okanagan Lake between October 01 **and** February 28 should not normally exceed six inches. In anticipated runoff years however, greater drawdowns may be necessary to accommodate the spring **runoff**.

Without long term forecasting, the Plan's recommendations for drought conditions are not possible to meet in practice, because during times of very low **inflows** into the lake, it is not possible to **maintain** the water levels high, because of demands on the system. For example during the winter months the Okanagan river flows must be maintained relatively high to avoid exposing sockeye salmon eggs.

The Plan's recommendations for flood conditions to draw the lake down prior to **freshet** is impossible to do in practice without causing damage to the lake kokanee population (see next section).

Clearly when the Plan's requirements for fish habitat and fish spawning are combined with requirements for flood and drought management there is a conflict. In our opinion, this conflict could be mitigated with long term trend forecasting, **i.e**. determining by **July/August** what the following spring's **snowmelt** runoff conditions were likely to be.

*B. **Implementation** Agreement **Report**:* Nearly all of the engineering work **outlined** in the Plan **was** undertaken during the period 1976 to 1982, and this document describes what was achieved. Of importance to lake levels and outflows are the following:

Okananan Lake intakes. In order for the intakes to be operable at an extreme low lake elevation of 340.4 m (1116.8 feet), the Plan advised that ***all irrigation and domestic intakes be adjusted (lowered) as required*** The Implementation Report quotes the Board as advising that any intake modifications should not be undertaken ***until such a time as an actual drought event may occur.*** This was because of 1). the expectancy that there was a high chance of zero benefit fiom these changes over the life expectancy of the these intakes, and 2). because the work could be done relatively quickly if needed. **All** new intakes (1977 onwards) were built to operate at a lake surface elevation of 340.4 m.

Sockeye salmon **flows**. The allowed flow for the period August 1 to September 15 were changed, to allow more flexibility in releasing flows **from** Okanagan Lake. The revised schedule was:

DATES	**FLOWS,** OLIVER GAUGING STATION	
August 1 to September 15	300 - 1000 ft^3/s	(8.5 - 28.3 m^3/s)
September 16 to October 31	350 - 550 ft^3/s	(9.9 to 15.6 m^3/s)
November 01 - April 30	175 - 1000 ft^3/s	(5.0 - 28.3 m^3/s)

"After February 1, flood control requirements are given **priority** over fishery flows and it may on occasion be necessary to ***exceed*** the 28.3 m^3/s upper limit".

Kokanee **Spawning**. Mention is made of a multi- agency water study concerning both salmon flows and conditions for **kokanee** (determining how to minimize the **drawdown** of Okanagan Lake during the winter months). One of the outcomes of this study were key water **surface** elevations that the operator should aim for in most years. These were

- February 1st flood control target elevation of 1121.3 feet, preceded by
- October 15th secondary target elevation of 1121.8 feet

> "If this secondary target level of 1121.8 A on October 15 is met, then the drop in lake level between October 15 and February 01 should not exceed six inches in most years".

The Implementation Agreement Report modifies Recommendation 40 of the Plan, to read:

> "To enhance shore spawning kokanee conditions over the fall and winter months, Okanagan Lake will be operated such that, when possible, the lake level is not greater than 1121.8 feet on October 15, subject to flow restrictions for sockeye salmon".

For reasons that are not known to us, the need to preserve water levels within a close range from the spawning period until 28 February (as envisaged in the Plan) were changed, and the February 01 date adopted. This modified date is too early to protect kokanee spawn, because emergence happens after this date, even in warmer than average winters, and approximately an additional six weeks are needed after emergence, for successful growth of the alevins in the shoreside gravel.

4.0 Other Selected Reports

Four reports are reviewed, as follows:

Summit Environmental Consultants Ltd., 1999. "Improved Seasonal Inflow Forecasting Models for **Okanagan** and Kalamalka **Lakes:** Final Report and **Users** Manual". For Ministry of Environment, Lands and Parks, Southern Interior Region. **80** pp plus Appendices.

The report focuses on forecasting of **expected** inflows into the Lake during the **spring/summer** period. The forecasts are made during the period beginning of February to beginning of May.

To assist in the operation of Okanagan and Kalamalka Lakes, forecasts of **freshet** period **inflow** to each lake are presently made four times per year, on '1 February, 1st March, ld April and '1 May. A prediction for the total lake inflow volumes fiom these dates, until 3ld July, is made every year.

Statistical models for inflow prediction were developed by government in **1984.** It later became apparent that there was a need to improve the performance of these models, particularly for results of the 1st February and 1st March predictions.

The **Summit** report tested previously used and new variables in the regression equations, including:

- Snow Water Equivalent at Key **AES** Stations in the Basin
- Surface **Inflow** Volumes for the Previous Three Months
- Forecast Period Precipitation fiom Canadian Institute of Climate Studies
- Groundwater levels
- Plateau reservoir storage
- Basin-wide Index of Snow Water Equivalent

A statistical procedure, principal components **(Garen)** analysis, was used to undertake the comparisons of modeled and actual flows. The result of the suggested new procedures is to substantially improve the early season forecasts for both lakes.

For reasons that are not explained, several of the suggested new variables were not included in the finally recommended equations. This may be because the effects of some variables are implicitly included in others, **e.g**. groundwater levels are expected to be correlated with the December to February lake inflow values in most years.

Obedkoff, W., 1994. **"Okanagan** Basin Water Supply". File No. **42500-60/S,** Study No. 384, Province of British Columbia, **Ministry** of Lands, Environment and Parks.

A review, including modeling of monthly inflows and outflows to Okanagan Lake and the downstream river, was carried out. The purpose of the review was to establish what additional future withdrawal of water from the system would be possible, under the operating conditions of the Plan, and assuming a worst case hydrological period, equal to three drought years in succession (as occurred in 1929 to 1931).

The conclusion of the report was that an additional 63 million m^3 per year of water could be abstracted **from** the system, if the maximum lake draw down **(i.e**. all the emergency storage) was used. Following this drought period, it would take three years of at least average inflow conditions for the lake water surface to return to its normal range. Management of flood events was not discussed. Winter fluctuations of Okanagan lake surface levels during drought periods were not discussed in the report.

McNeil, R *1991.* "Report on Frequency Analyses of Flood Flows and Levels for Okanagan **Valley, Mainstem** System", **File** No. SS111, S5211. Water Management Division, Hydrology Section, Ministry of Environment, Lands and **Parks.**

An analysis of peak flow events, and maximum water levels for Okanagan, **Skaha** and **Osoyoos** Lakes and for the Okanagan River are computed. 200 year and 20 year return period events are listed. The author is **careful** to point out that because the system is dominated by releases **from** Okanagan Lake, and because this is not natural but is man controlled, the normal statistical projections do not apply. However in the absence of a better way to proceed, the statistical analyses were done, with the data set being tested with all the data (1921 to 1990) and modern data (1951 to 1990). A change in operating procedure for the system occurred after 1951, hence the split in the data set.

The values computed provide guidance for flood construction levels around the lakes, and for peak channel capacity. The report states that with 0.61 m **freeboard** above the 200 year peak water **surface** level for Okanagan Lake, the flood construction level should be 343.66 m, the same level that has been in effect since 1974.

Operational aspects, such as the need to lower Okanagan Lake ahead of a predicted high mow pack season, are not discussed.

Shepherd, B. G. 199%"Impacts of Regulating Okanagan Lake Water Levels on Shore Spawning Kokanee Stocks". Okanagan Sub-region Fisheries Section, Ministry of Environment, Lands and Parks. Draft report, 17 February 1997.

The history of water level regulation activities is summarized in the first section of the report. Reference is made to Volume 1 of "Report of Joint Board of Engineers on Okanagan Flood Control" 1946. The outlet of Okanagan Lake prior to 1909 was controlled by a natural bar, whose elevation was surveyed at 341.3 m. Control dams, with sills at elevations 340.8 m were constructed in 1914-15, and 1920. The present control structure was built in 1953, with the sill set at 339.75 m. Clearly with the gates of the control structure open, there is the capability of discharging much more water at low lake levels than could be discharged in the original (uncontrolled) situation. This is because the sill elevation has been lowered.

The report includes a section concerning an overview of water level patterns, and a section concerning an overview of kokanee shore spawning. The Okanagan Lake shore spawning kokanee stock utilize water depths of less than 3 m for spawning, with depths of less than 0.5 m preferred. In a recent report by Dill (1997), the majority of embryos were found at substrate depths of 15-20 cm, with a prediction for optimal incubation conditions at about 15-30 cm. The likelihood of increased mortality of kokanee embryos fiom man induced water level drops during the winter months is discussed. Mention is made of declines in the kokanee population due to other causes, such as the introduction of *Mysis* in the Lake.

5.0 Licensed Withdrawals of Water from Okanagan Lake

A considerable volume of water is taken from Okanagan Lake for industrial, agricultural and domestic purposes. Licensed and actual withdrawal of water may be significantly different. This is particularly true of large waterworks licenses which are intended to provide for future growth in demand.

Currently, there are about 919 water licenses allowing diversion of water fiom the Lake. The water licenses grant a total diversion volume of 110 Mm^3 of water annually, and this diversion volume is about 23% of the mean annual outflow of Okanagan River at Penticton. Out of the 919 water licenses, 17 licenses *grant* about 83% of the total diversion volume, with each license allowing more than 1 Mm^3 diversion annually. The *city* of Kelowna has the highest licensed abstraction volume of 47 Mm^3/year, mainly for municipal water supply purposes. Table 3 shows the *sum* of diversions from Lake Okanagan, the total number of licenses, and details of the major licenses.

TABLE 3

Licensed Maximum Withdrawals of Water from Okanagan Lake

Licence No.	Licensed Purpose	Quantity at POD	UNITS	Annual Diversion Volume ($1000 m^3$)	Priority Date	Licensee	Licensee address
C032633	COOLING	12,000,000	GD	19,910	19670203	RIVERSIDE FOREST PRODUCTS LTD	820 GUY ST KELOWNA BC V1Y7R5
C032829	WATERWORKS LOCAL AUTH	3,285,000,000	GY	14,929	19670726	KELOWNA CITY OF	1435 WATER ST KELOWNA BC V1Y1J4
C022362	WATERWORKS LOCK AUTH	2,190,000,000	GY	9,953	19541108	KELOWNA CITY OF	1435 WATER ST KELOWNA BC V1Y1J4
C108281	WATERWORKS LOCAL AUTH	1,934,500,000	GY	8,791	19690623	WINFIELD & OKANAGAN CENTRE IRRIG MST	10591 OKANAGAN CNTRE RD E WINFIELD BC
C032828	WATERWORKS LOCAL AUTH	1,825,000,000	GY	8,294	19670726	KELOWNA CITY OF	1435 WATER ST KELOWNA BC V1Y1J4
C027158	WATERWORKS LOCAL AUTH	1,095,000,000	GY	4,976	19611214	KELOWNA CITY OF	1435 WATER ST KELOWNA BC V1Y1J4
C019680	WATERWORKS LOCAL AUTH	912,500,000	GY	4.147	19500803	PENTICTON CITY OF	171 MAIN ST PENTICTON BC V2A5A9
C025236	WATERWORKS LOCAL AUTH	730,000,000	GY	3.318	19590212	PENTICTON CITY OF	171 MAIN ST PENTICTON BC V2A5A9
C040839	WATERWORKS LOCAL AUTH	730,000,000	GY	3,318	19720724	KELOWNA CITY OF	1435 WATER ST KELOWNA BC V1Y1J4
C032615	WATERWORKS LOCAL AUTH	584,000,000	GY	2,654	19670606	SUMMERLAND CORP OF THE DISTRICT OF	BOX 1 9 SUMMERLAND BC V0H1Z0
C014633	WATERWORKS LOCAL AUTH	547,500,000	GY	2,488	19380802	KELOWNA CITY OF	1435 WATER ST KELOWNA BC V1Y1J4
C015910	IRRIGATION LOCAL AUTH	1,800	AF	2,221	19310320	GLENMORE-ELLISON IMPROVEMENT DIST	C/O D MCFADDEN 445 GLENMORE RD KELOWNA BC
C066159	WATERWORKS (OTHER)	1,077,000	GD	1,787	19861120	TRANSPORTATION & HIGHWAYS MINISTRY OF	523 COLUMBIA ST KAMLOOPS BC V2C2T9
C019098	WATERWORKS LOCAL AUTH	365,000,000	GY	1,659	19490510	KELOWNA CITY OF	1435 WATER ST KELOWNA BC V1Y1J4
C034312	IRRIGATION LOCAL AUTH	1,000	AF	1,234	19680925	OKANAGAN-SIMILKAMEEN REGIONAL DIST OF	101 MARTIN ST PENTICTON BC V2A5J9
C018611	IRRIGATION	900	AF	1,110	19480316	OKANAGAN INDIAN BAND	RR 7 COMP 20 SITE 8 VERNON BC V1T7Z3
C020914	IRRIGATION LOCAL AUTH	900	AF	1,110	19520605	WEST BENCH IRRIGATION DISTRICT	PO BOX 537 PENTICTON BC V2A6K9
				91,897	SUM OF THE ABOVE 17 LICENCES CONTRIBUTING TO OVER 83% OF THE TOTAL DIVERSION FROM THE LAKE.		
				18,424	OTHER 902 LICENSEES		
				110,521	TOTAL LICENCED DIVERSION FROM OKANAGAN LAKE		

Note that

- 1). a considerable return flow exists for water pumped fiom the lake and utilized for various purposes. A factor of 65% return flow is recommended in the Plan, for **municipal/domestic** water withdrawals, and
- 2). Several water users abstract water in volumes that are **significantly** below their annual licensed amounts.

S i the inception of the Plan in 1974, **all** intakes have been designed to **function** at an extreme low lake level of 340.4 m. We do not know how many old or non-complying intakes exist.

6.0 Annual Water Outflows and Approximate Inflows for Okanagan Lake

The intent of this Section is to provide some approximate values for understanding of the nature of the water management problem. Because the regional climate is very dry, the runoff fiom year to year fluctuates a great deal. During dry years and wet years net inflows of about 100 Mm^3 and **1000** Mm^3 respectively are noted. The year 1997 provided a record inflow volume of about 1400 Mm^3.

Few of the tributary streams are gauged, so that annual inflow volumes can only be approximately listed based on a hydrological balance for Okanagan Lake. This has a large error attached, because the evaporation from the lake is not known, is hard to determine, and contributes an important part of the water balance.

Ministry of Environment, Lands and **Parks** Flood Forecasting Branch computed data on net annual inflow volumes into **Okanagan Lake,** for the periods 01 October to 30 September the following year. **Information** is updated yearly.

These inflows were computed **from** outflows, with a correction for changes in storage in Okanagan **Lake.** Outflows were taken fiom data fiom Water Survey of Canada gauging station No. **08NM050,** ***Okanagan*** River at Penticton (see Figure Al, Appendix A). Evaporation is not included in the calculation, so **actual inflows** are considerably higher than the computed **net inflows.** The data **concerning** net annual inflows **from** 1922 to 1997 are shown in the Appendix **A,** as Figure A2.

Data for climate are available in the Plan, see for example Table 3.2, page 64, Technical Supplement No. 1. The long term **annual** precipitation averaged for the whole basin is about 560 mm. For the lake itself the precipitation is much lower, and high summer temperatures lead to a relatively high lake **evaporation**. Evaporation from the lake basin is estimated as 420 mm per year. **The** long term average precipitation on the lake is estimated to be 315 mm per year, which is about 56% of the average precipitation over the whole basin.

Evaporation **from** the lake is hard to assess. Temperature differences fiom one year to the next have a significant effect on annual total evaporation. The value listed in the Plan is 965 mm per year, and we believe that an error band of ±15% should be attached to this value, because of uncertainties in the true value, and because of year to year fluctuations. This value is confirmed approximately by other published data (Calculated Lake Evaporation data) based on meteorological measurements at Summerland and Kelowna, (see Canadian Climate Normals, 1951-1980, Volume 9).

The mean evaporation fiom the lake is thus approximately three times that of the precipitation on the lake. Evaporation is a major factor in the water budget for the lake (see Table 4). A summary of mean annual water budget values is given in Table 4.

Errors of measurement are estimated as follows:

- up to 15% is estimated for assessment of precipitation and up to 15% for evaporation directly from the lake,
- up to 5% error on the net runoff fiom the basin and flow measurements at Penticton, and
- an error of up to 15% on abstraction, to account for abstracted flows less than licenced amounts.

Table 4. Approximate Annual Water Budget for Okanagan Lake

Description	Annual Volume (Mm^3)	Estimated Error* (Mm^3)	Record period	Reference
Net runoff on the Lake basin (without Lake)	780	±39	1921-1970	Canada-BC Okanagan Basin Agreement, 1974
Contribution from Precipitation on the Lake	100	± 15	1931-1960	Assuming annual precipitation on the lake of 315 mm ± 48 mm
Evaporation from the Lake	330	●50	1921-1970	Canada-BC Okanagan Basin Agreement, 1974
Abstraction	*96*	± 14	1997 Record	BC Government Water Rights Information System
Retumflow from abstraction	62	±9		Return flow assumed as 65% of the total diversion
Outflow at Penticton	470	±24	1921 to present	HYDAT CD ROM

***Our estimate of measuring/calculation error.**

7.0 Historic Water Level Fluctuations

7.1 Review of Water Surface Levels during the Past 40 Years

An analysis of water surface elevations on 01 February was carried out, see Figure 4. In addition, a check was made to determine the amount of surf' lowering of the lake during the period 15 October to 01 February the following year (over winter drawdown).

Since the inception of the Plan in 1974,

- the water surface on 01 February has been within the range +0. 15 m to -0.28 m of the target level of 341.77 m. The lowest level (01 Feb 1993) in recent years was associated with drought runoff conditions the previous summer.

- the water surface on 15 October has been within the range +0.33 m to -0.36 m of the target level of 341.92 m. The two highest levels were prior to the preparation of the Implementation Report, and the lowest level was associated with the 1992 drought.

- the overwinter drawdown has exceeded 6 inches (15 cm) eight years out of 23 years. Since the Implementation Report of 1982, the overwinter drawdown has exceeded 6 inches (15 cm) three years in 15 years, see Figure 4.

Graphs of water surface elevations for the whole year, for all years from 1960 to 1997, are shown with an expanded time scale in Appendix A, Figure A3.

7.2 Drawdowns in the Recent Years during the Spawning Period

The weeks after 01 February are important to kokanee spawning success, because emergence does not happen until approximately 01 March, and approximately six weeks are needed after this date for the successful growth of the alevins in the gravel. Therefore, the water surface level fluctuation up to the end of March is considered vital for the overall development of the fish. An analysis of water surface drawdown for the period between 15 October and 01 April of the next year was carried out. Results are given on Figure 5. The water surface elevations for the last 38 years are given in Appendix A, Figure A3, with special marks on the 15 October and 01 April levels.

Since the inception of the Okanagan Plan in 1974, the lake surface drawdown has exceeded 6 inches (15 cm) in 17 years out of 23 years, and has exceeded 12 inches (30 cm) 9 years in the past 23 years, see Figure 5.

8.0 Outflow History

Okanagan Lake outflows, measured at Water Survey of Canada gauging station ***Okanagan*** River at ***Penticton,*** Station No. **08NM050** for the years 1960 to present have been plotted. These are shown as 7 day moving average flows, for clarity of plotting, see Figures A4. Also shown on the same scale are Okanagan Lake water surface levels, as 7-day moving averages. The range of outflows is fiom an average annual **minimum** flow of about 5.7 m^3/s to an average **annual** maximum flow of about 46 m^3/s.

During the last 40 years the largest daily outflow **was** 85.6 m^3/s, recorded on 7th and 8th ***August*** 1997. This wide range of flows is associated with the arid nature of the Okanagan basin, and the large differences in runoff **from** one year to the next. Note the very low peak outflows in years such as 1992, associated with very poor snow pack conditions the previous winter.

9.0 Linkage between Southern Oscillation Index and Snow **Pack/Runoff**

9.1 Introduction

The **SOI** is a measure of **sea** level barometric pressure differences between Tahiti and Darwin in the southern hemisphere tropics. During El **Niño,** unusually high atmospheric sea level pressures develop in the western tropical Pacific ocean, and unusually low **sea** level pressures develop in the eastern tropical Pacific **ocean.** An **accompanying** phenomenon is significant heat build up in the **surface** water of the eastern Pacific Ocean, changing the ocean surface temperature by as much as 1 to 2 degrees centigrade over an extremely large area. This heat build up takes many months to happen, and once it has arisen, several months are needed before the heat anomaly is dissipated. In this period, **tracking** patterns of the **jet** stream over the northern Pacific **Ocean** are **affected,** with consequences for the rain and snow bearing winds that bring **frontal** storms to our area.

The **SOI** index measurements are updated monthly and published on the Internet, so access to the data is quick and inexpensive. **SOI** measurements are available for a very long period, (year 1882 to present).

Ministry of Environment Flood Forecast Center has recently provided a **WEB** site **information** bulletin concerning the effect of **El Niño** global climate fluctuations on runoff in British Columbia. The most noticeable effect of the El **Niño** is along the south coast and in the southern interior. For the Okanagan basin, the April 1st 1997 **snowpack** was below **normal** a large (74%) proportion of the time following El **Niño** events, having on average 16% less snow than normal.

An excellent unpublished report (G.A. McBean, **1994),** summarizes the possibilities for long term climate and runoff predictions for Canada. **McBean** found that streamflow in most BC regions was positively correlated with **SOI** for lagged correlations.

There is good preliminary evidence that climate and **streamflow** in the US northwest is influenced by world scale climate fluctuations. For example **Redmond** and Koch (1991) have shown that the **ENSO** (El **Niño** Southern Oscillation) measured by the **SOI** has an effect on temperature, precipitation and runoff in mountainous parts of the US northwest. Snow accumulation is **likely** impacted by combined changes in temperature and precipitation. During El **Niño** years, the winter climate tends to be both slightly drier, and slightly warmer than normal. Additionally there is a suggestion of **cause-effect** relationshiis, with the **SOI** change preceding the climate change by as much as 4 to 6 months.

9.2 Snow Pack Correlation

We selected a number of snow survey measurement stations in the Okanagan Station. Three of the snow courses selected were near the **Okanagan** basin, but outside the catchment area. At each snow course station, the maximum snow pack was investigated to check the possible **correlations** with the Southern Oscillation Index values. In the analysis, the Southern Oscillation Index was averaged over the six months period of April to September for each year and correlated to the **maximum** snow pack of the following year.

Results of the correlation analysis show that there is a reasonable correlation between the six month average **SOI** and maximum snow pack for **some** of the high altitude stations. For eight of the **twelve** stations the correlation is good, and for four of the twelve stations the correlation is very good. For one station (Mount **Kobau)** there is no significant correlation.

The coefficient values are given in Table 5.

Table 5: Correlation between April to September Mean SOI and Following Year Maximum Snow Pack.

Station Name & Course Number	Elevation at Station (m)	Record Length (years)	Record Period	Correlation Coefficient
Trout Creek, Course No. 2F01	1430	61	1935-97	0.390
Summerland Reservoir, Course 2F02	1280	56	1942-97	0.449
Graysoke Lake, Course No. 2F04	1810	27	1935-97	0.470
Mission Crack, Course No. 2F05	1780	58	1939-97	0.523
Whiterocks Mountain, Course No. 2F09	1830	41	1953-97	0.210
Silver Star Mountain, Course No. 2F10	1840	39	1959-97	0.338
Isintok Lake, Course No. 2F11	1680	33	1965-97	0.453
Mount Kobau, Course No. 2F12	1810	32	1966-97	0.092
Esperon Creek(upper), Course No. 2F13	1650	28	1966-97	0.337
Morrissey Ridge No 1, Course No. 2C09[a]	1860	28	1961-88	0.576
Mission Ridge, Course No. 1C18[b]	1850	29	1967-95	0.548
Blackwall Peak, Station No. 2G03P[c]	1940	30	1968-97	0.518[d]

[a]The station is located in East Kootenay Sub Basin.
[b]The station is located in Middle Fraser Sub Basin.
[c]The station is located in Similkameen Sub Basin.
[d]Water equivalent data used in stead of snow pack

9.3 *Runoff Correlation for High Altitude Basins*

We selected number of medium and high altitude basins in the region with Water Survey of Canada gauges, see Figure 6. Some of these basins were close to the Okanagan valley, but in different river systems. The flow during the snow melt period was totaled, and possible correlations with the Southern Oscillation Index values were investigated.

In almost all basins analyzed, over two thirds of the annual flow appears in the two months of the spring freshet. The volume of flow over the two months was checked for any significant correlation with the mean Southern Oscillation Index of the previous summer. In the analysis, the Southern Oscillation Index was averaged over three to six months for the periods of April to September, May to September, June to September, July to September, and June to August.

In all the cases best correlation was found between the mean Southern Oscillation Index over the six months period of April to September to the total volume of flow in the two months of May and June of the following year.

In summary, results of correlation analysis show that there is a significant correlation between the six month average SOI and stream flows in the following Spring. The coefficients are given in Table 6. Most of the correlation coefficients are significantly different from zero (the null hypothesis) at the 0.1% level. Scatter plots of the average stream flow for the months of May and June versus the average April to September Southern Oscillation Index are given in Figure 7 for selected basins. The examples on Figure 7 cover basin with areas ranging from 5 km^2 to 185 km^2.

Table 6: Medium and High Altitude Basins: Correlation between April to September Mean SOI and Following Year May to June Stream Flows.

Station Name & Number	Record Length	Elevation at Station (m)	Basin Area (km^2)	Correlation Coefficient
Whipsaw Creek below Lamont Creek, Station No. 08NL036	30	785	185	0.545
Camp Creek at mouth near Thirsk, Station No. 08NM134	29	1005	33.9	0.556
Vaseux Creek above Terrace Creek, Station No. 08NM171	24	1100	117	0.320
Two Forty Creek near Penticton, Station No. 08NM240	11	1630	5	0.607
Two Forty One Creek near Penticton, Station No. 08NM241	11	1610	4.5	0.565
Dennis Creek near 1780 Metre Contour, Station No. 08NM242	10	1780	3.73	0.517
Trapping Creek near Mouth, Station No. 08NN019	28	1040	144	0.605

9.3 Correlation of Streamflows allowing for Interannual Water Storage

The larger basins in the Okanagan region are characterised by ephemeral creek flows, small dams that overflow only during high runoff years, and creek flows where groundwater storage/release are important. In these basins, storage from previous years affects the volume of stream flows in the spring freshet, because of inter-annual storage and release. This storage may be associated with small dams that top up and overflow only during high runoff years, and with groundwater flows. During a wet year, where the annual total flow volume is clearly higher than the long term average flow, the storage gets higher and adds to the flows of the following year. In years following wet years, the stream flows are the result of the current year runoff and groundwater contribution from the past.

ı order to analyze the relationship between the SOI and the spring freshet flow in these basins, a ude mechanism was used to account for the groundwater contribution to streamflow in the year ıllowing wet years. For the data set analyzed it was assumed that about 25% of the previous years ʼere wet, 25% of the previous years were dry, and the other 50% of the previous years were neither ʼet nor dry. For the wettest 25% of years only, an adjustment for groundwater contribution was ıade.

he following rough procedure was used to account for the groundwater contribution, based on revious year (V_{i-1}) water volumes:

Compute, long-term mean annual flow volume, V_{mean}
Compute standard deviation of annual flow volume over the record period, V_{std}
Set upper flow volume bound $= V_{mean} + 0.7 * V_{std}$
Compare annual flow volume of previous year (V_{i-1}) with upper flow volume bound
If V_{i-1} is greater than the upper flow volume bound, then it is assumed that the volume sent into groundwater storage is above average and enhanced groundwater flows augment the following year's freshet. Thus, the adjusted fieshet runoff volume of the following year will be the measured freshet flow volume minus the groundwater contribution based on the previous year's high flows.
If V_{i-1} lies below the upper flow volume bound, then groundwater storage change does not affect the following year fieshet much differently fiom average, and no adjustment is necessary to the following year measured fieshet flow volume.

The formula that was used for adjustment of flows to allow for groundwater storage was simple, and was done for trial purposes only. We have made no attempt to optimize the formula, or to relate it to surface and groundwater physical conditions in the various watersheds. The purpose of the formula, was to demonstrate a trial allowance for the groundwater contribution fiom the previous year when base flow conditions were much larger or much smaller than average.

The formula was:

Two month (May and June) adjusted flow rate, $Q_{2miadj} = Q_{2mi} - C^* \Delta Q_{2mi-1}$

in which:
Q_{2mi} is the two month average flow rate happening in the present year,
ΔQ_{2mi-1} is the difference between the average two month flow rate and the two month flow that happened in the previous year
C^* is an inter year groundwater flow contribution coefficient ($C^* = 0.21$ was used for most basins and $C^* = 0.42$ was used for the Okanagan basin).

fter these adjustments for groundwater contribution, the SOI averaged over the six months period f April to September for each year was correlated to the spring freshet flow volume of the following ear. Correlation coefficient values for one very large and three large basins, characterised by high :orage associated with small dams that top up in wet years and large valley bottom areas, are given ı Table 7. The results of this analysis showed that there is up to a 13% improvement in correlation etween SOI and following year freshet flow, when inter-annual storage associated with groundwater ow is taken into consideration.

he final column of Table 7 shows that correlations are medium to very good. In particular there is medium correlation for the Okanagan basin itself In view of the contribution of spring and early ummer rain events to the Okanagan river flows, the correlation is surprisingly high.

catter plots of the average stream flow for the months of May and June versus the average April to eptember Southern Oscillation Index are given in Figure 8A for the Okanagan basin and in Figure B for Mission Creek basin. Plots are provided for 1). the original data, and for 2). the data corrected or interseasonal storage. The trend shows that the smaller the value of the 6 month (April to eptember) SOI, the smaller is the May to June inflow the following year.

igure 8A shows that in 13 out of 66 years when the 6 month SOI is less than -0.6, the following ear May-June inflow volume to Okanagan Lake was no larger than 33% above the long term verage inflow. In most of these low value SOI years, the following year May-June runoff was low. There were no significantly above normal events during these years. Three of these 13 years were the nost serious drought years of record.

Table 7: Correlation between April to September Mean SOI and Following Year May to June Stream Flows with Interannual Groundwater Storage Considerntion.

Station Name & Number	Record Length	Elevation at Station (m)	Basin Area (km^2)	Correlation Coefficient without storage	Correlation Coefficient with interannual storage effect
Camp Creek at mouth near Thirsk, Station No. 08NM134	30	1005	33.9	0.556	*Insignificant storage**
Vaseux Creek above Terrace Creek, Station No. 08NM171	24	1100	117	0.320	*Insignificant storage•*
Two Forty Creek near Penticton, Station No. 08NM240	11	1630	5	0.607	*Insignificant storage•*
Two Forty One Creek near Penticton, Station No. 08NM241	11	1610	4.5	0.565	*Insignificant storage•*
Dennis Creek near 1780 Metre Contour, Station No. 08NM242	10	1780	3.73	0.517	*Insignificant storage**
Trapping Creek near Mouth, Station No. 08NN019	28	1040	144	0.626	*Insignificant storage**
Whipsaw Creek below Lamont Creek, Station No. 08NL036	30	785	185	0.545	0.566
Mission Creek near East Kelowna, Station No. 08NM116	28	427	811	0.556	0.561
Tulameen River Near Penticton, Station No. 08NL024	44	640	1760	0.437	0.464
Okanagan Lake, Net Inflow	66		6090	0.359	0.406

**Small watersheds at medium and high altitude; small inter-annual storage.*

9.4 Use of Southern Oscillation Index to assist in Seasonal Trend Analysis

The relationship between the **snowmelt** component of stream flows and the Southern Oscillation Index was found apparent in our analysis. The significant correlation coefficient between the **six** month average (April to September) SOI, and the volume of flows in the two Spring months of the following year enables a rough advance forecasting method to be developed for the expected volume of the spring **freshet**. Although this is likely to be most **useful** in predicting the snow melt component of the flow, and this component is less than 50% of the spring runoff in some years, we believe the procedure will enable seasonal trends to be predicted, well in advance.

Advance knowledge of a normal or below average snow pack year ahead would enable the Water Management Branch **staff (who** are responsible for controlling the lake levels) to feel **confident** about going into a Fall season with relatively high water levels in Lake.

We have demonstrated a loose correlation between runoff conditions and global climate indicators measured the previous summer. Figure 8 shows that in 13 out of 66 years when the 6 month SOI is less than -0.6, the May-June **inflow** volume to Okanagan Lake was no larger than 33% above normal. Only in one year (1983) was there an exception, otherwise there were no **events** during these years that were significant floods. Three of these 13 years were the most serious drought years of record.

Several months of advance notice about approximate snow pack will allow adjustments to be made to lake levels starting as early as the first day of September, or possibly earlier. The possibility of using water level adjustments to **Okanagan** Lake with one target level **for** the majority of years, and another target level for low **SOI** (predicted **drought/normal)** years is discussed in the next Section.

10. Conclusions & Recommendations

Management of water levels in the Okanagan Lake system and particularly Okanagan Lake itself is of great strategic importance to the Okanagan valley. Irrigation/municipal demands, flood reduction, fisheries habitat and spawning, and recreation uses all depend on how wisely the flow of water is managed. Control over the opening and closure of the outlet gates of Okanagan Lake at Penticton is crucial to determining lake levels and downstream flows.

Lake levels for Okanagan Lake presently set by Province of British Columbia were adopted in 1982, when the Okanagan Basin Implementation Agreement Report was finalised. Of particular importance are target water levels at key dates, such as February 1st and October 15th. Because of very large storage in Okanagan Lake in relation to discharge capability at Penticton, adjustment of lake levels takes several weeks of time. Procedures that will give operators more time and more flexibility in operating the lake are desired.

Presently the lake is operated most of the time at elevations that are higher than may be necessary. This creates problems for fisheries during high runoff years because of the need for extensive lowering of the lake during the winter months.

We have demonstrated a loose correlation between spring runoff conditions and global climate indicators measured the previous summer. Figure 8 shows that in 13 out of 66 years when the 6 month SOI is less than -0.6, the May-June inflow volume to Okanagan Lake was no larger than 33% above normal. Only in one year (1983) was there an exception, otherwise there were no events during these years that were significant floods. Three of these 13 years were the most serious drought years of record. This means that a climate situation causing normal or drought conditions in lake inflows the following spring can be foreseen, and plans to keep the lake level higher than in the majority of years can be initiated on 1st September. Adjustments to the outflow at Penticton can be started at this time, and the decision about the target water surface elevation confirmed on 30" September.

With long range weather trend predictions improving, we believe that it may be possible to operate the lake during the winter at lower elevations than previously used, without increasing the risk to irrigation water supplies. This leads to the idea of utilizing:

1). a revised water surface target for 01 February, such as 1120.7 feet (341.6 m), 0.15 m less than presently used, with a similar revision to the water surface target for 15" October. These water surface elevation values would be used for the majority of years.

2). The same water surface target as used at present on 01 February (341.75 m) for low SOI years only.

In planning for implementation of this idea, some important checks should be undertaken to see if it is feasible. Water flow and water balance studies using the historic data set should be carried out to check on the following points:

*A). **Proposed** lower wafer **surface elevations** during the majority of years:*

- Would the additional amount of water that will be released during late **summer/fall** imply flows at Oliver gauging station in excess of 28.3 m^3/s (see presently allowed flows, page 10).

- Would there be sufficient water in storage to supply the normal **winter/spring** minimum release flows (3 m^3/s) **from** Okanagan Lake.

- Would the lake be able to fill during **spring/summer** the majority of years, following winters when the revised target is used.

B). Allowed flows at Oliver gauging station: Are the presently allowed flows during the period August 1'' to October **31''** unnecessarily conservative. Would it be possible to release up to 45 m^3/s (for example) during this period.

C). Lower lake levels: Would the proposed revised range of lake levels cause problems with dock owners **(fixed** elevation docks).

Part of a **future** procedure, if feasible, will involve River Forecast Centre, Ministry of Environment, Lands and Parks carrying out an assessment of the previous 4-6 months **SOI** value prior to August 31st year. Other global indicators of heat and weather in the Pacific Ocean may be available and may be preferable predictors (better than **SOI** value) of seasonal **runoff**. These indicators should be tested for correlation with Okanagan basin **runoff**. Yearly recommendations should be made for the Okanagan system, if runoff conditions for the following spring are likely to be significantly larger than, or **significantly** smaller than average. Adjustments to lake outflows to be started by Water Management staff on **1st** September of each year, to allow water level to meet target levels on 15'' October and 1'' February. Confirmation of the decision on the target water level should be made on 30th September.

ACKNOWLEDGMENTS

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Ministry of Environment, Lands and Parks. A review of the Conclusions section of the report was kindly provided by the Water Management Branch, Southern Interior Region.

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Figures

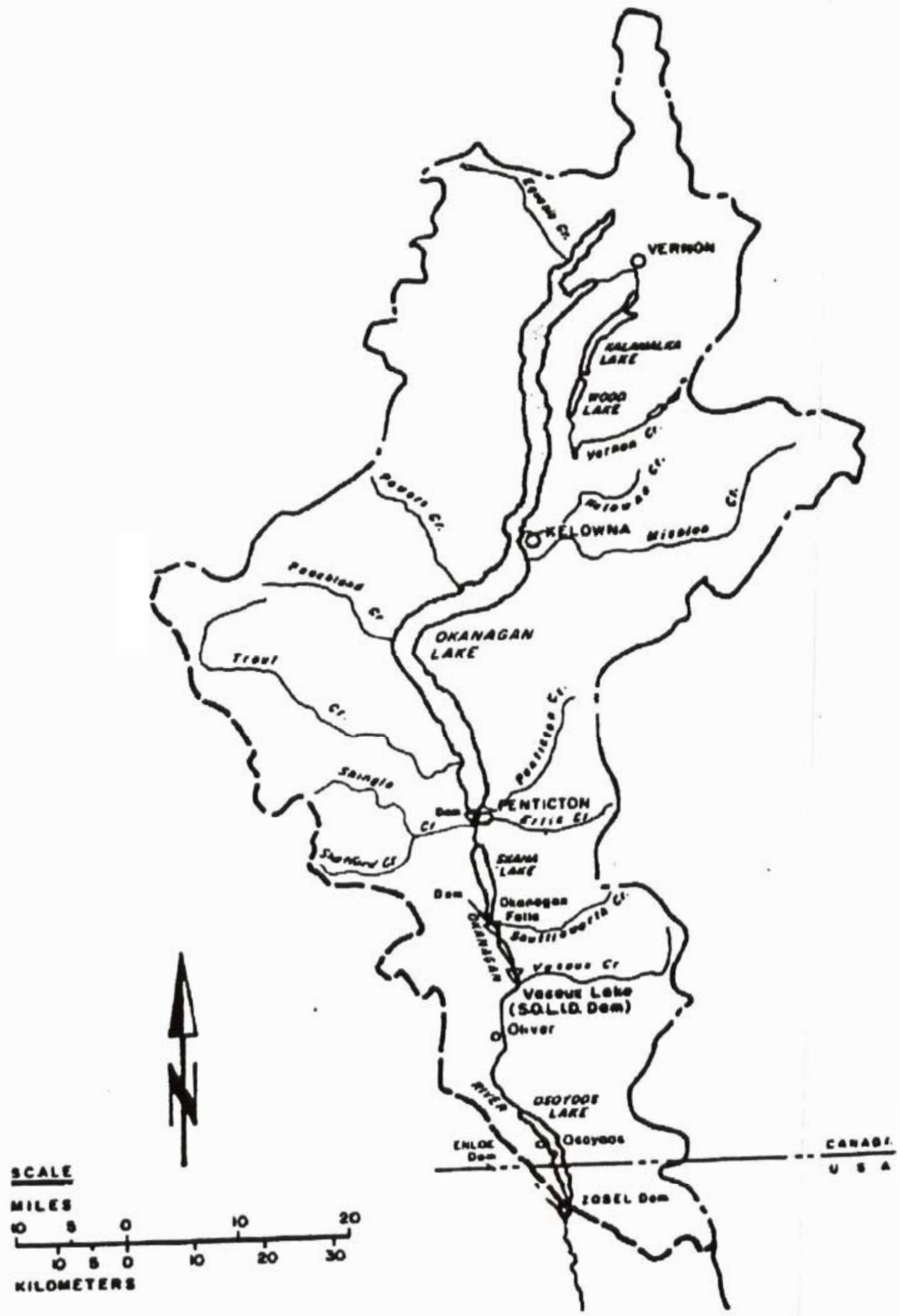
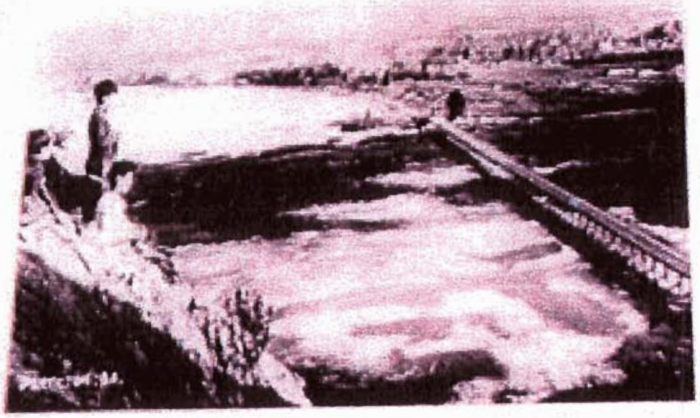


FIGURE 1: THE OKANACAN BASIN



A long wooden bridge crossed the slough west of Penticton, 1914-28.

1942 flood waters in front of the Incola Hotel

FIGURE 2: HISTORICAL WATER LEVELS AT PENTICTON

OKANAGAN LAKE TARGET WATER SURFACE LEVELS AND SILL ELEVATIONS

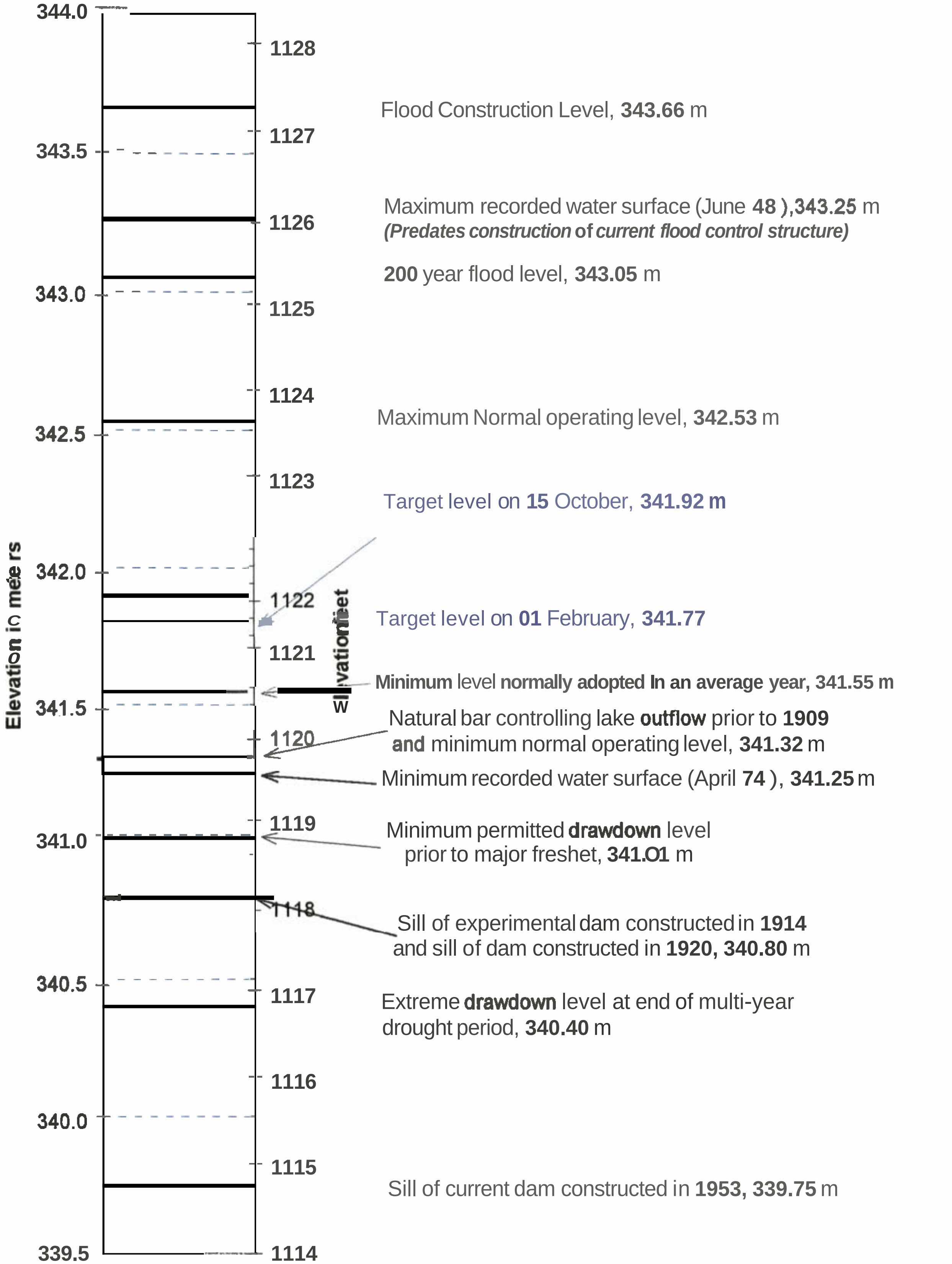


FIGURE 3

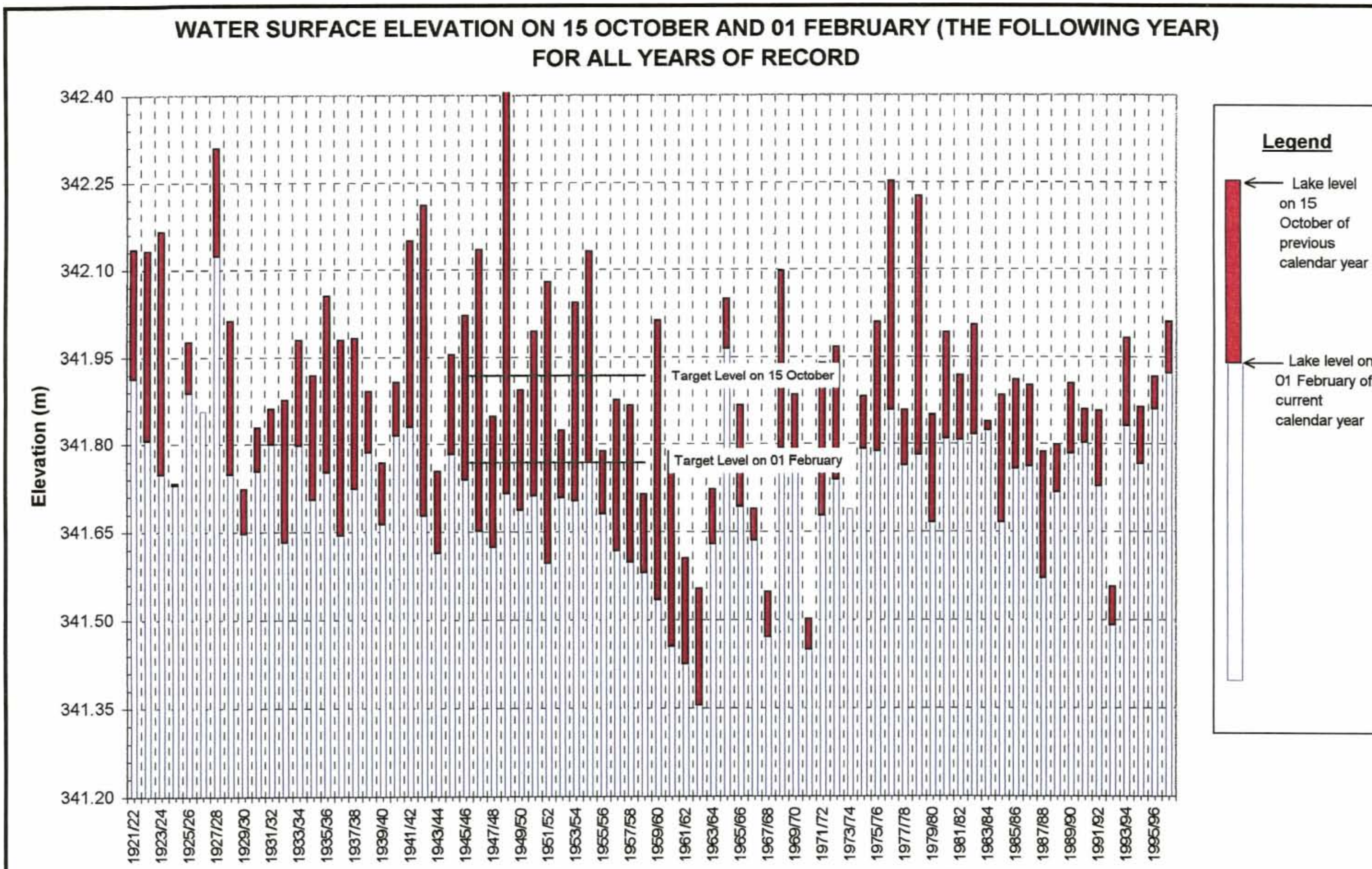

WATER SURFACE ELEVATION ON 15 OCTOBER AND 01 FEBRUARY (THE FOLLOWING YEAR)
FOR ALL YEARS OF RECORD
Elevation (m)
342.40
342.25
342.10
341.95
341.80
341.65
341.50
341.35
341.20
Target Level on 15 October
Target Level on 01 February
1921/22
1923/24
1925/26
1927/28
1929/30
1931/32
1933/34
1935/36
1937/38
1939/40
1941/42
1943/44
1945/46
1947/48
1949/50
1951/52
1953/54
1955/56
1957/58
1959/60
1961/62
1963/64
1965/66
1967/68
1969/70
1971/72
1973/74
1975/76
1977/78
1979/80
1981/82
1983/84
1985/86
1987/88
1989/90
1991/92
1993/94
1995/96
Legend
Lake level on 15 October of previous calendar year
Lake level on 01 February of current calendar year

FIGURE 4

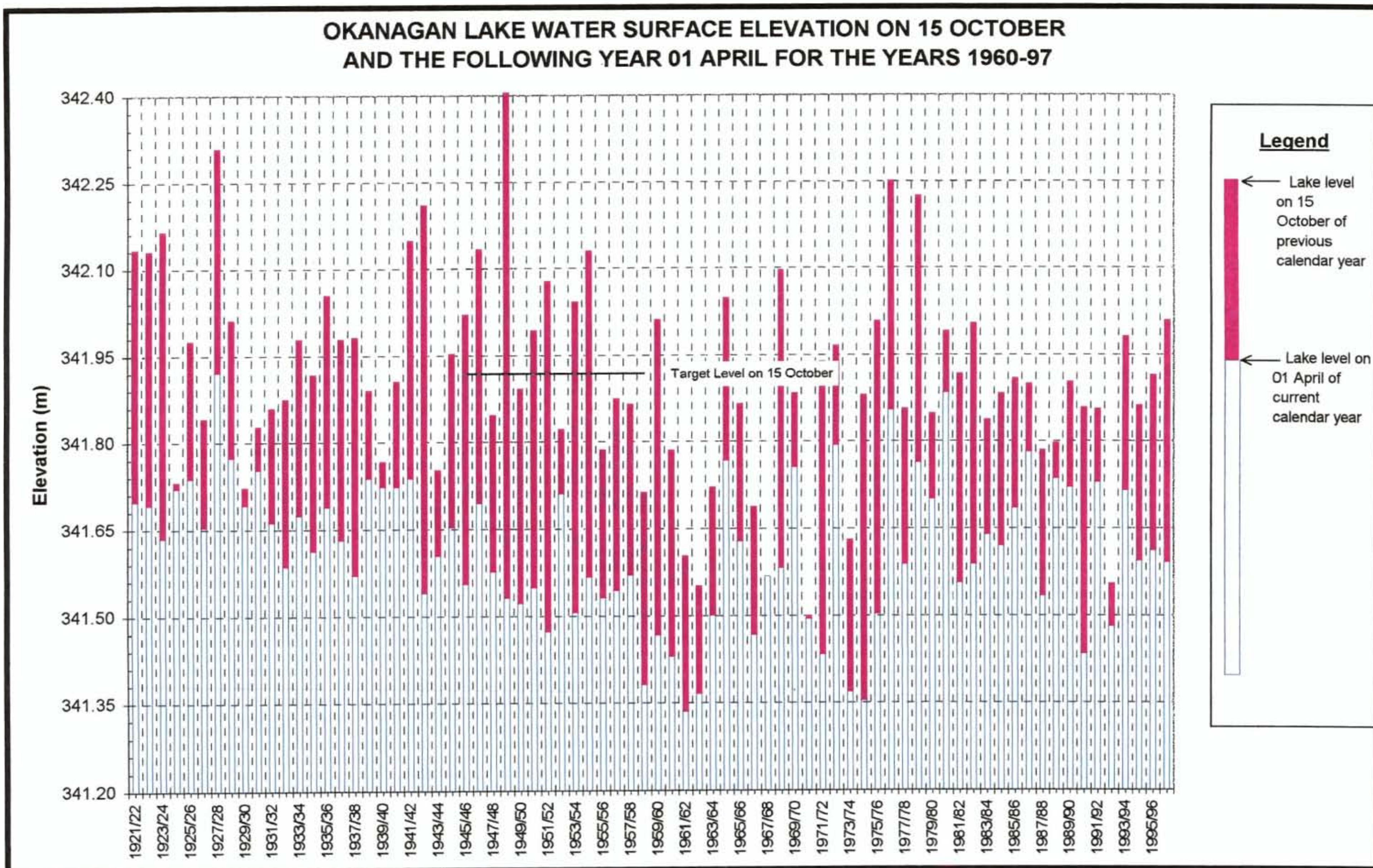

OKANAGAN LAKE WATER SURFACE ELEVATION ON 15 OCTOBER
AND THE FOLLOWING YEAR 01 APRIL FOR THE YEARS 1960-97
Elevation (m)
342.40
342.25
342.10
341.95
341.80
341.65
341.50
341.35
341.20
Target Level on 15 October
1921/22
1923/24
1925/26
1927/28
1929/30
1931/32
1933/34
1935/36
1937/38
1939/40
1941/42
1943/44
1945/46
1947/48
1949/50
1951/52
1953/54
1955/56
1957/58
1959/60
1961/62
1963/64
1965/66
1967/68
1969/70
1971/72
1973/74
1975/76
1977/78
1979/80
1981/82
1983/84
1985/86
1987/88
1989/90
1991/92
1993/94
1995/96
Legend
Lake level on 15 October of previous calendar year
Lake level on 01 April of current calendar year

FIGURE 5

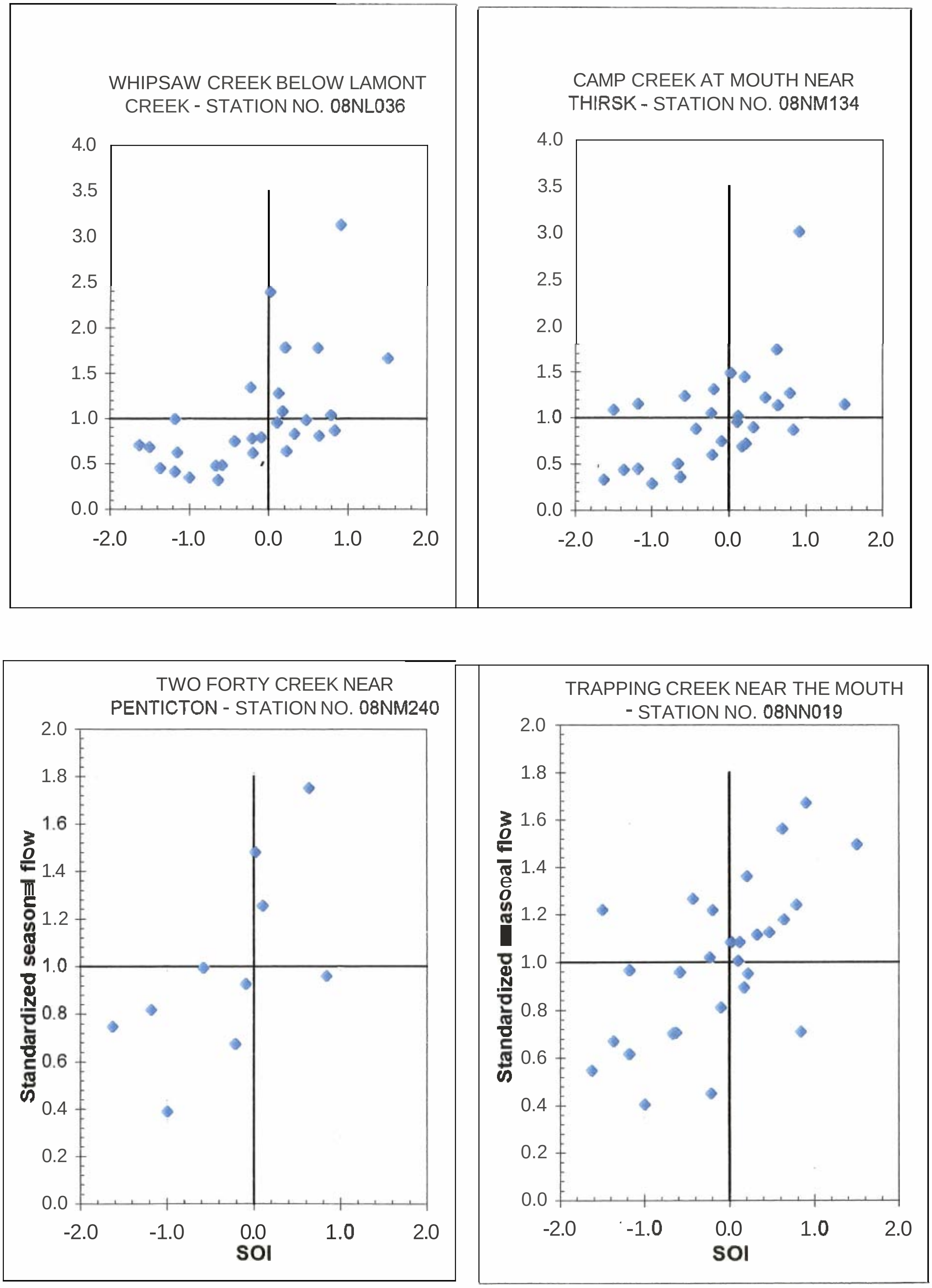
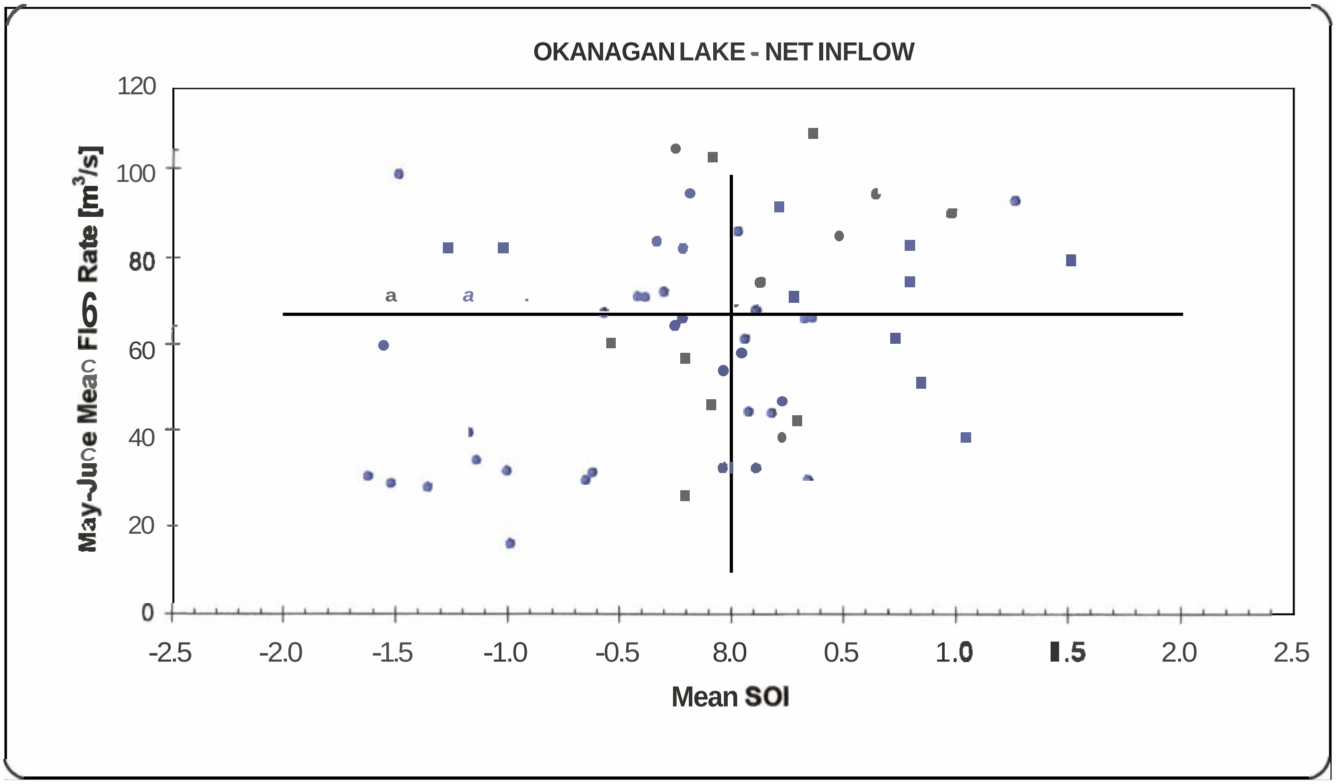


FIGURE 7: SNOW MELT RUNOFF CORRELATION, SELECTED BASINS

APRIL-SEPTEMBER SOUTHERN OSCILLATION INDEX AND FOLLOWING YEAR VALUES FOR MAYNUNE FLOWS



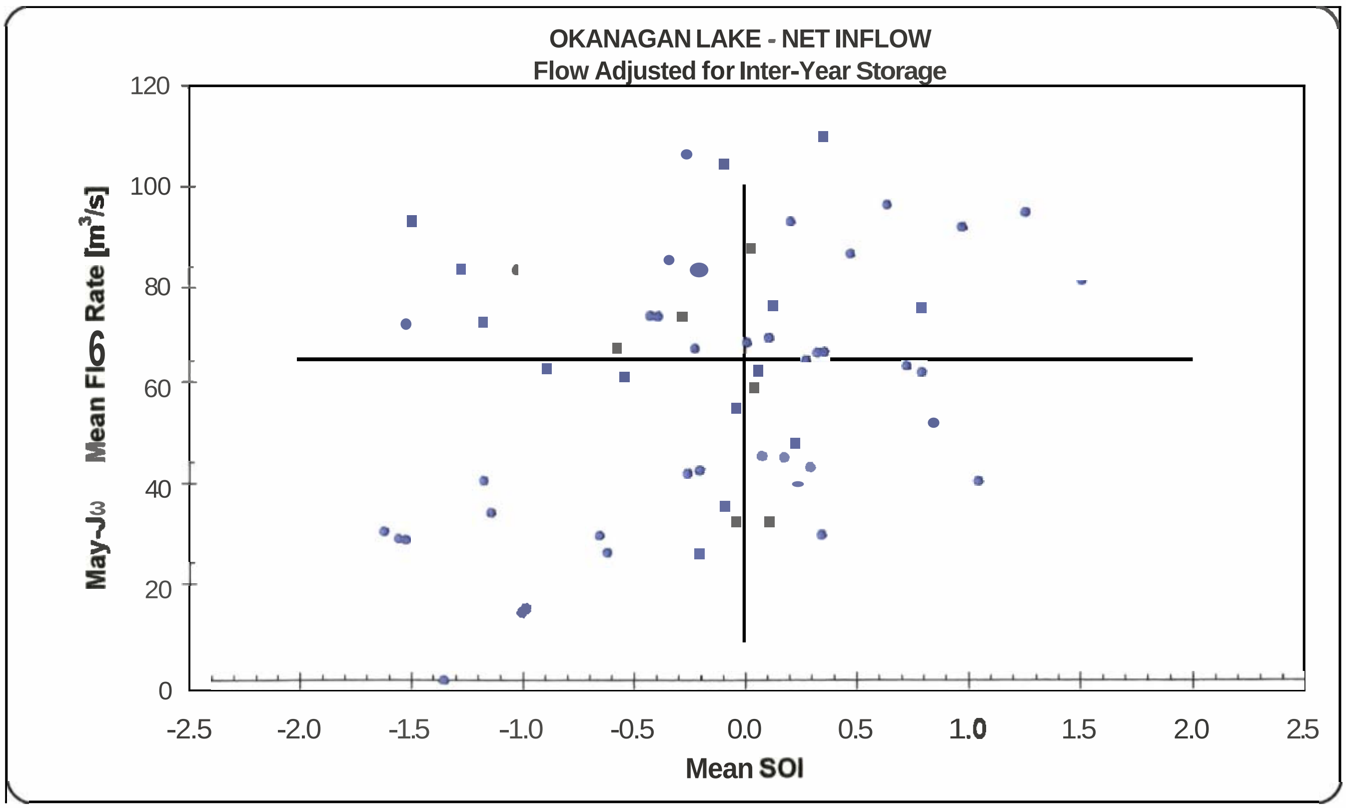
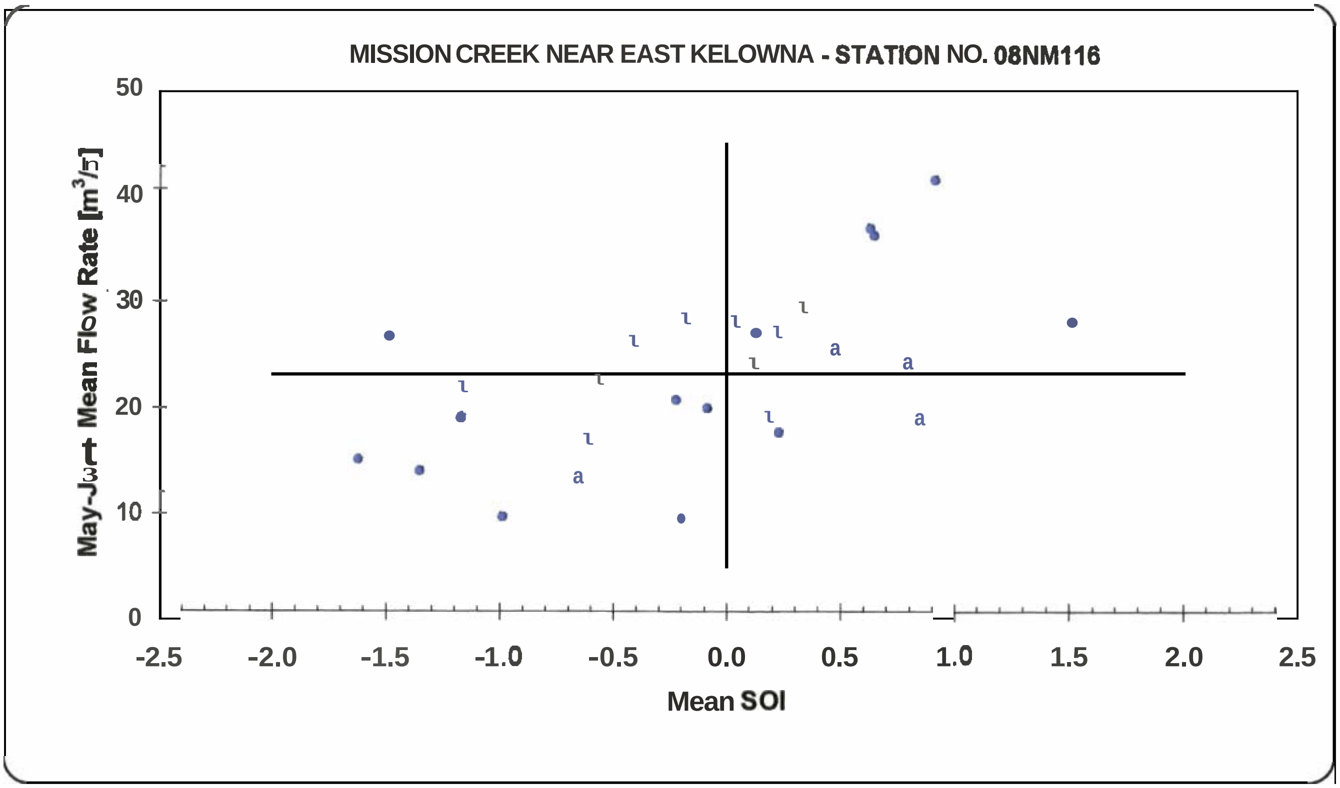


FIGURE 8A: SNOW MELT RUNOFF AND SOI CORRELATION, OKANAGAN BASIN

APRIL-SEPTEMBER SOI AND FOLLOWING YEAR VALUES FOR MAY-JUNE FLOWS



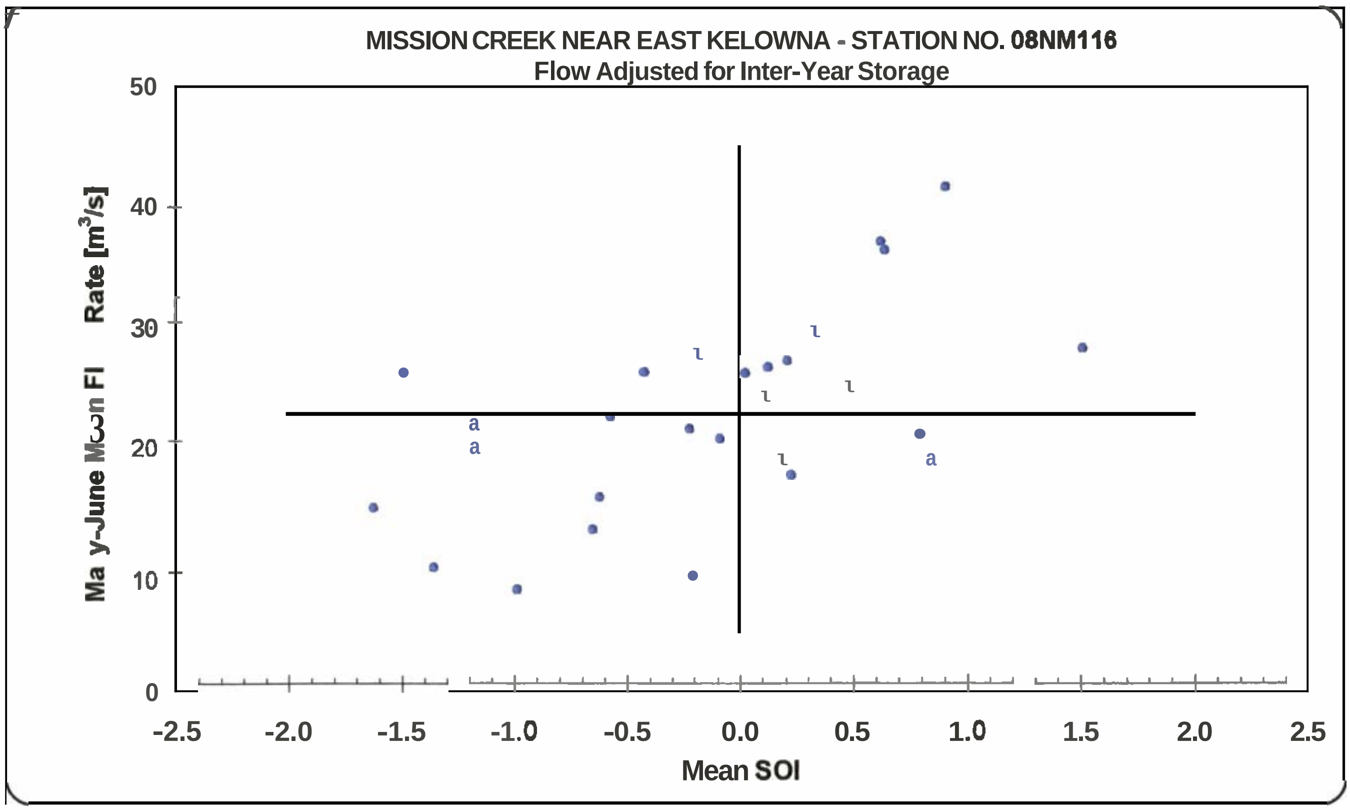


FIGURE 8B: SNOW MELT RUNOFF AND SOI CORRELATION, MISSION CREEK BASIN

APRIL-SEPTEMBER SOI AND FOLLOWING YEAR VALUES FOR MAYJUNE FLOWS

Appendix A

HYDROLOGICAL DATA
OKANAGAN LAKE

MEAN ANNUAL FLOWS AT OKANAGAN RIVER AT PENTICTION
STATION NO. 08NM050

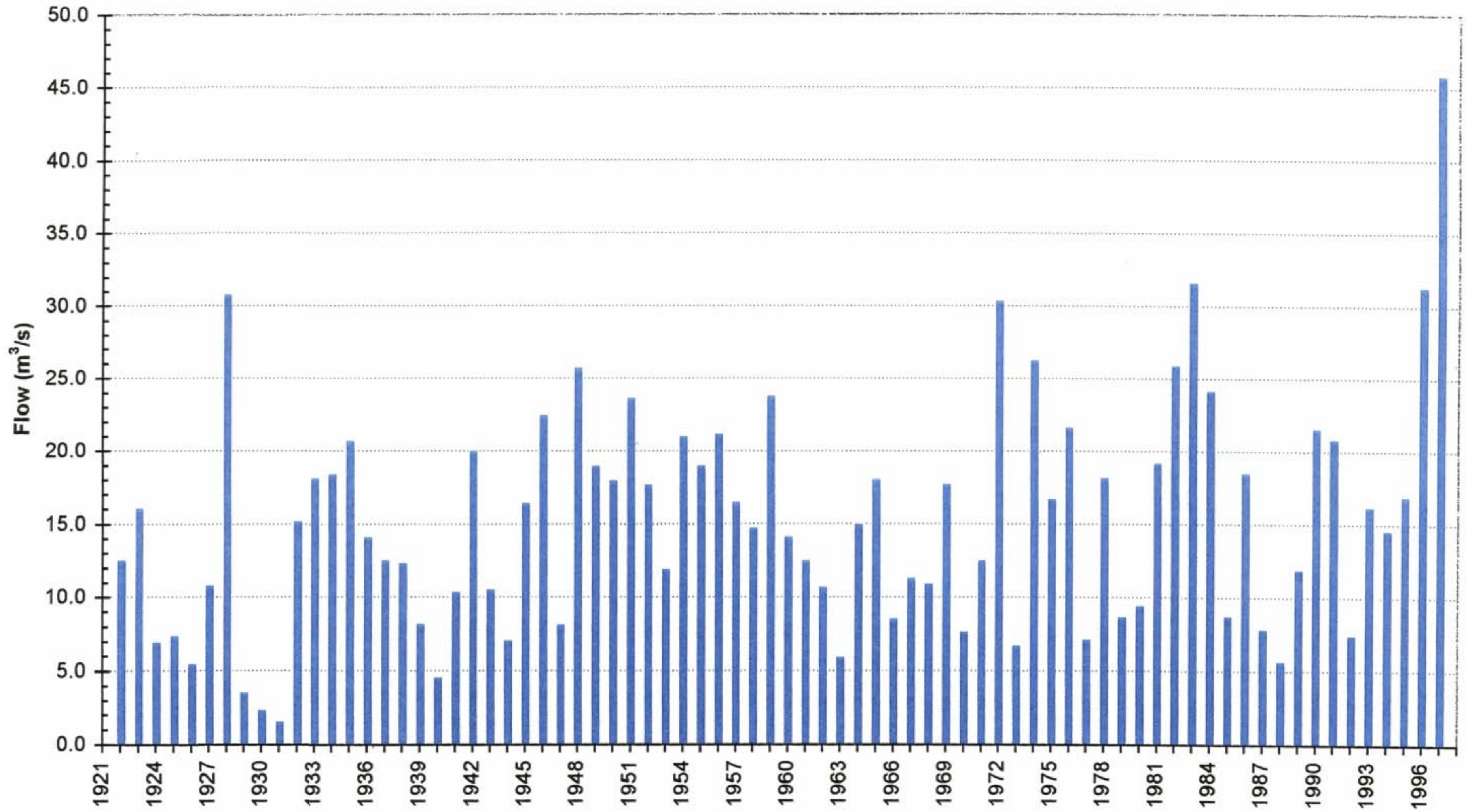
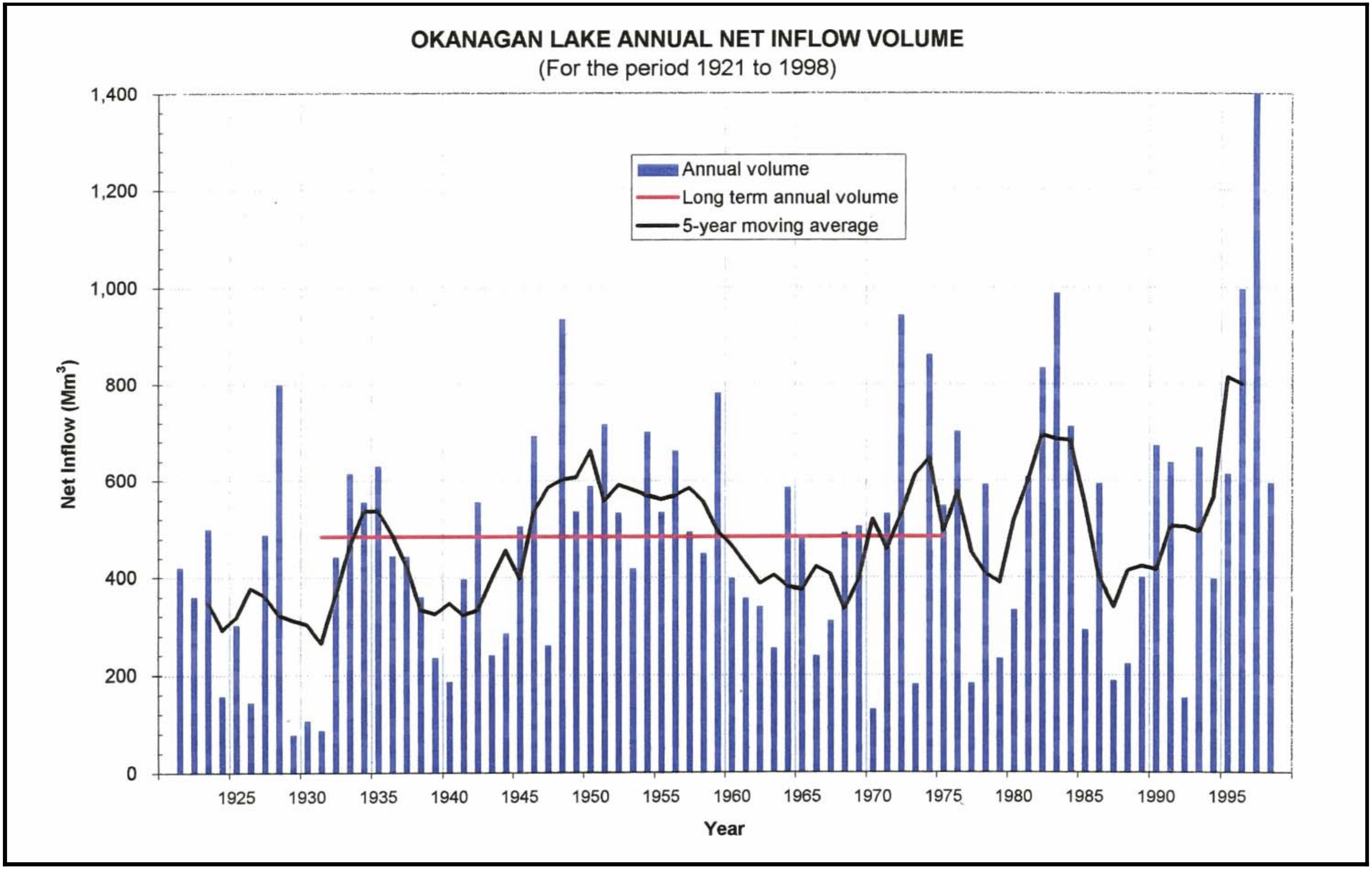


FIGURE A1



Netinflw.xls: Annual Inflow

FIGURE A2 (1 OF 2)

Ward & Associates Ltd.
Water Engineering & Hydrology

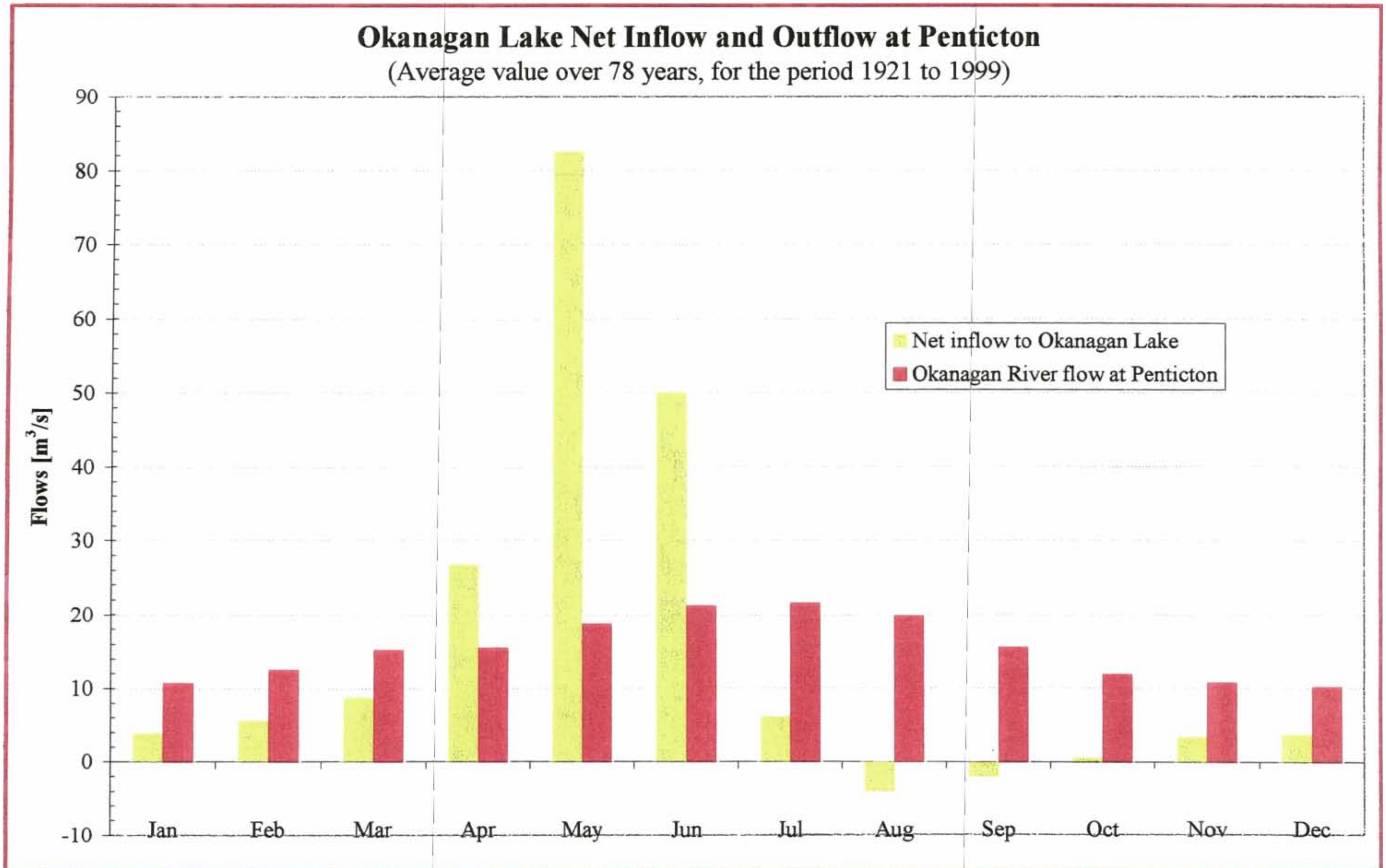
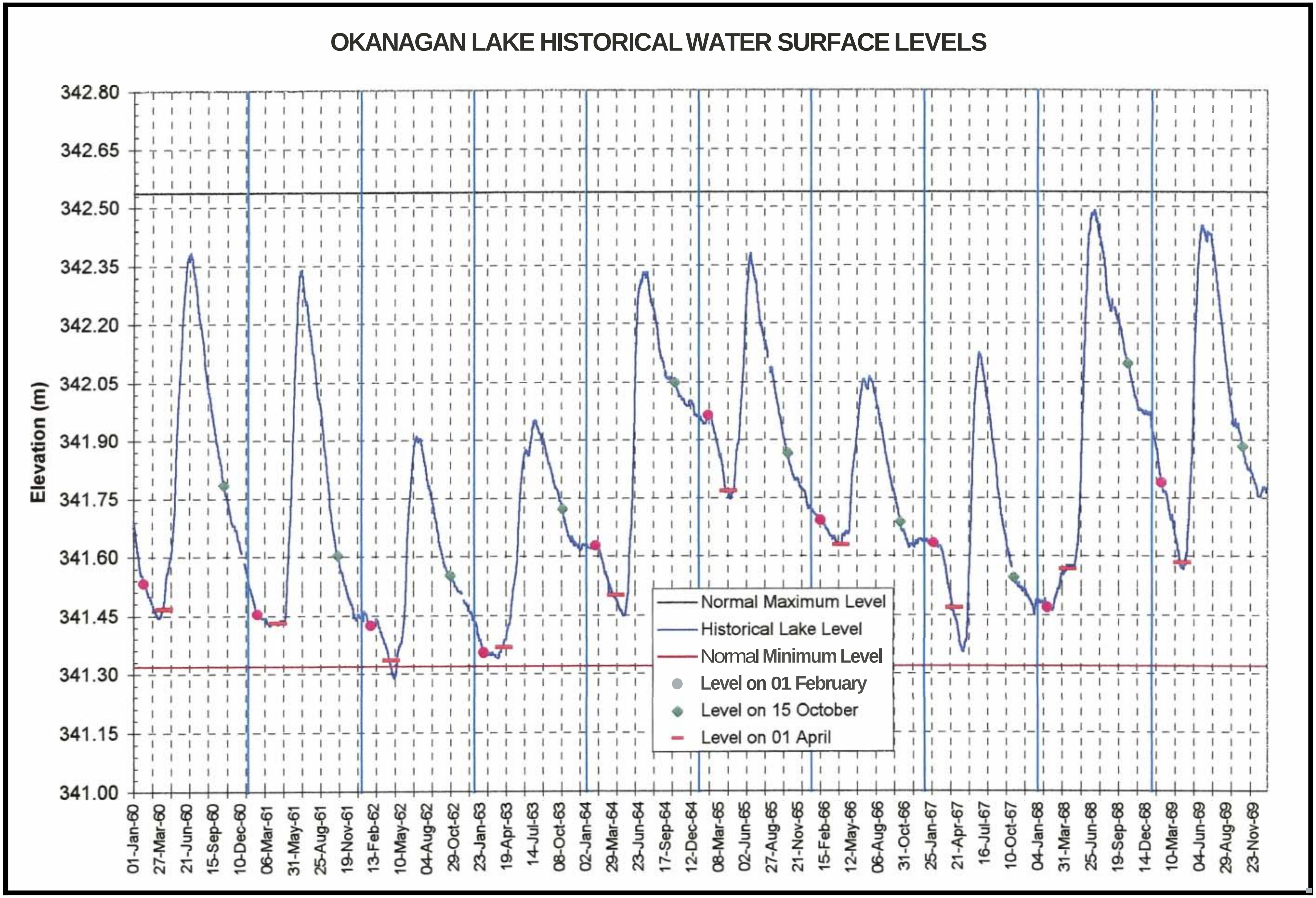
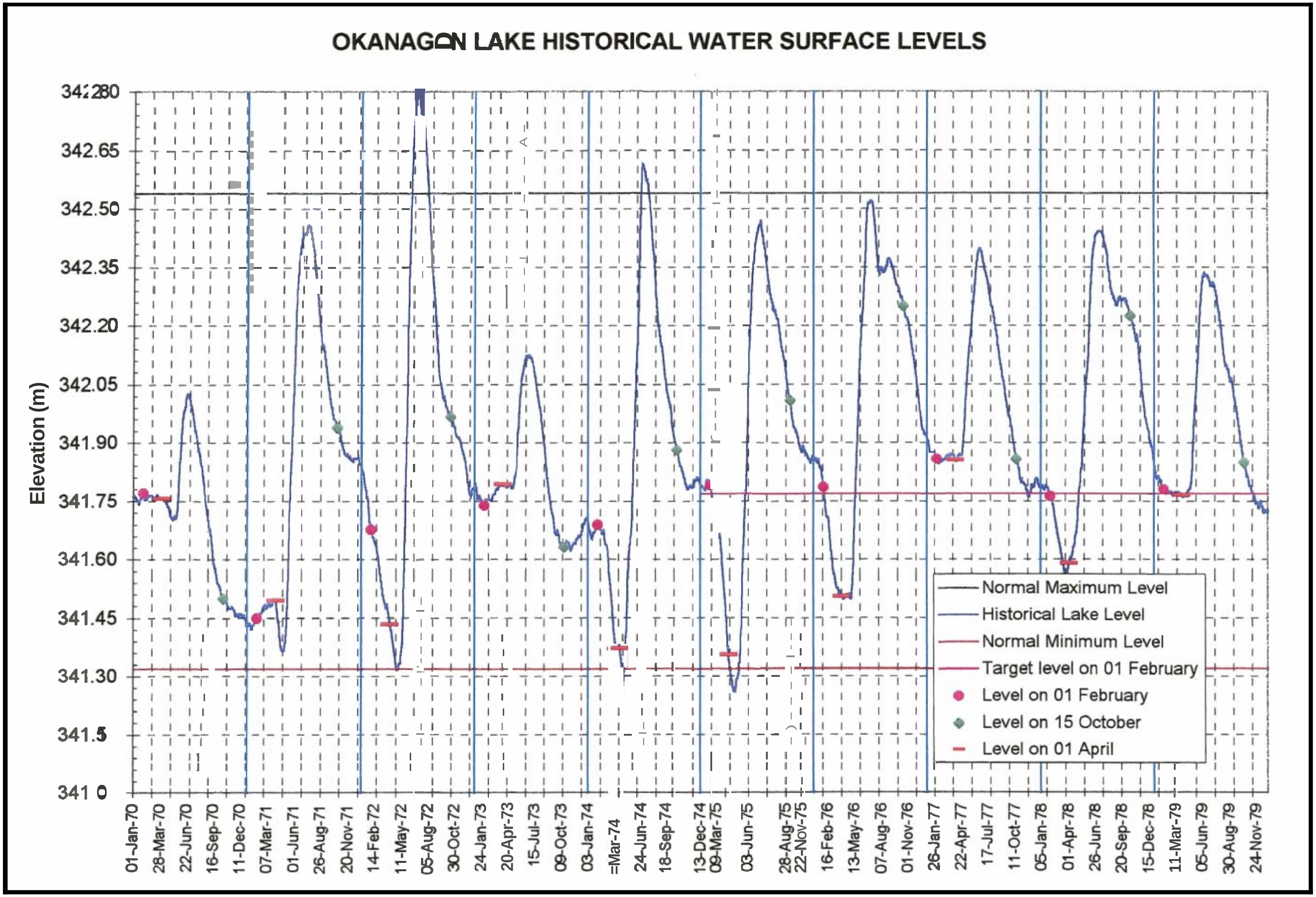


FIGURE A2 (2 OF 2)


OKANAGAN LAKE HISTORICAL WATER SURFACE LEVELS
Elevation (m)
342.80
342.65
342.50
342.35
342.20
342.05
341.90
341.75
341.60
341.45
341.30
341.15
341.00
01-Jan-60
27-Mar-60
21-Jun-60
15-Sep-60
10-Dec-60
06-Mar-61
31-May-61
25-Aug-61
19-Nov-61
13-Feb-62
10-May-62
04-Aug-62
29-Oct-62
23-Jan-63
19-Apr-63
14-Jul-63
08-Oct-63
02-Jan-64
29-Mar-64
23-Jun-64
17-Sep-64
12-Dec-64
08-Mar-65
02-Jun-65
27-Aug-65
21-Nov-65
15-Feb-66
12-May-66
06-Aug-66
31-Oct-66
25-Jan-67
21-Apr-67
16-Jul-67
10-Oct-67
04-Jan-68
31-Mar-68
25-Jun-68
19-Sep-68
14-Dec-68
10-Mar-69
04-Jun-69
29-Aug-69
23-Nov-69
Normal Maximum Level
Historical Lake Level
Normal Minimum Level
Level on 01 February
Level on 15 October
Level on 01 April

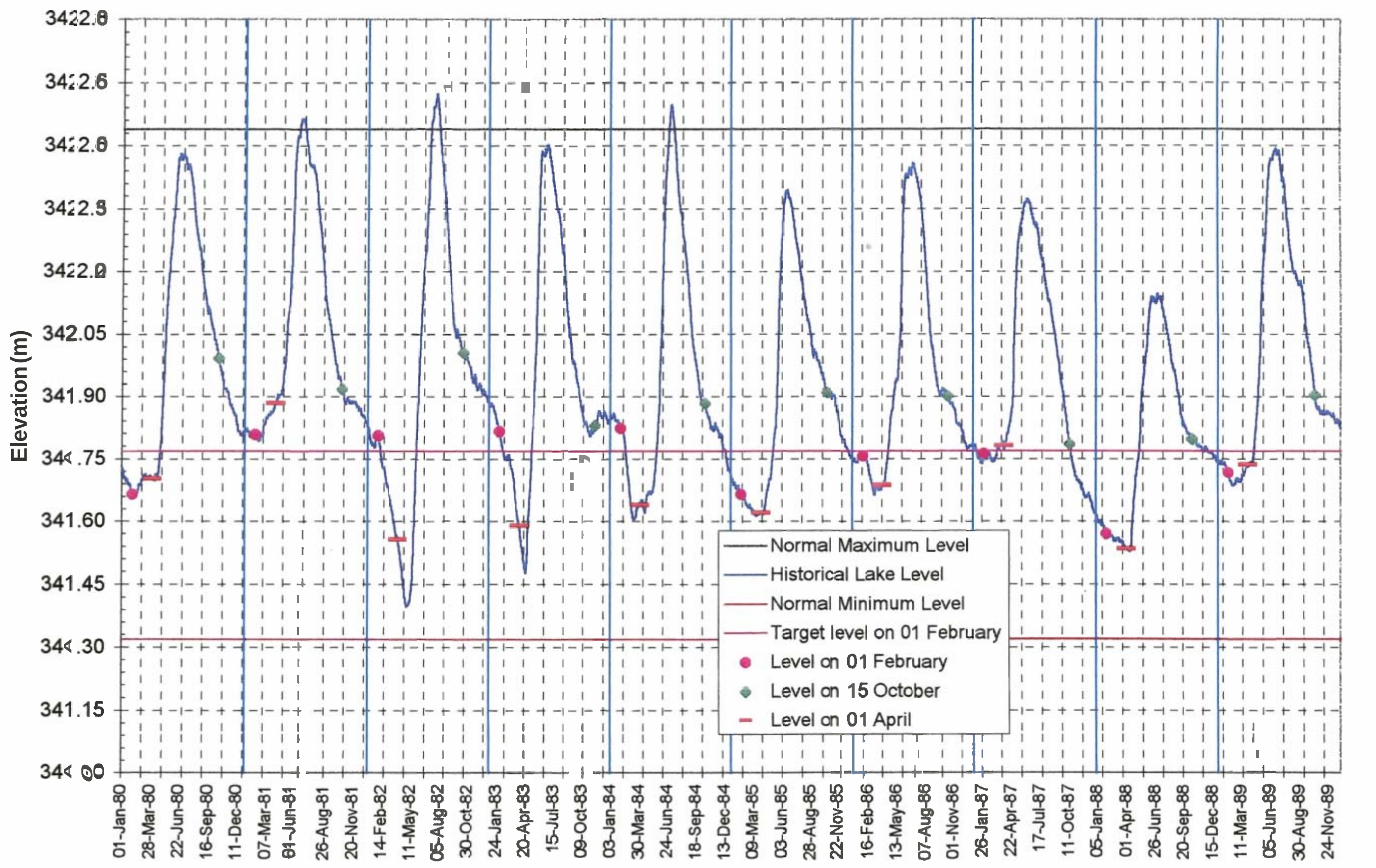


Kelowna levels up to 1999.XLS: Level 70s

FIGURE A3 (2 OF 4)

Ward & Associates Ltd.
Water Engineering & Hydrology

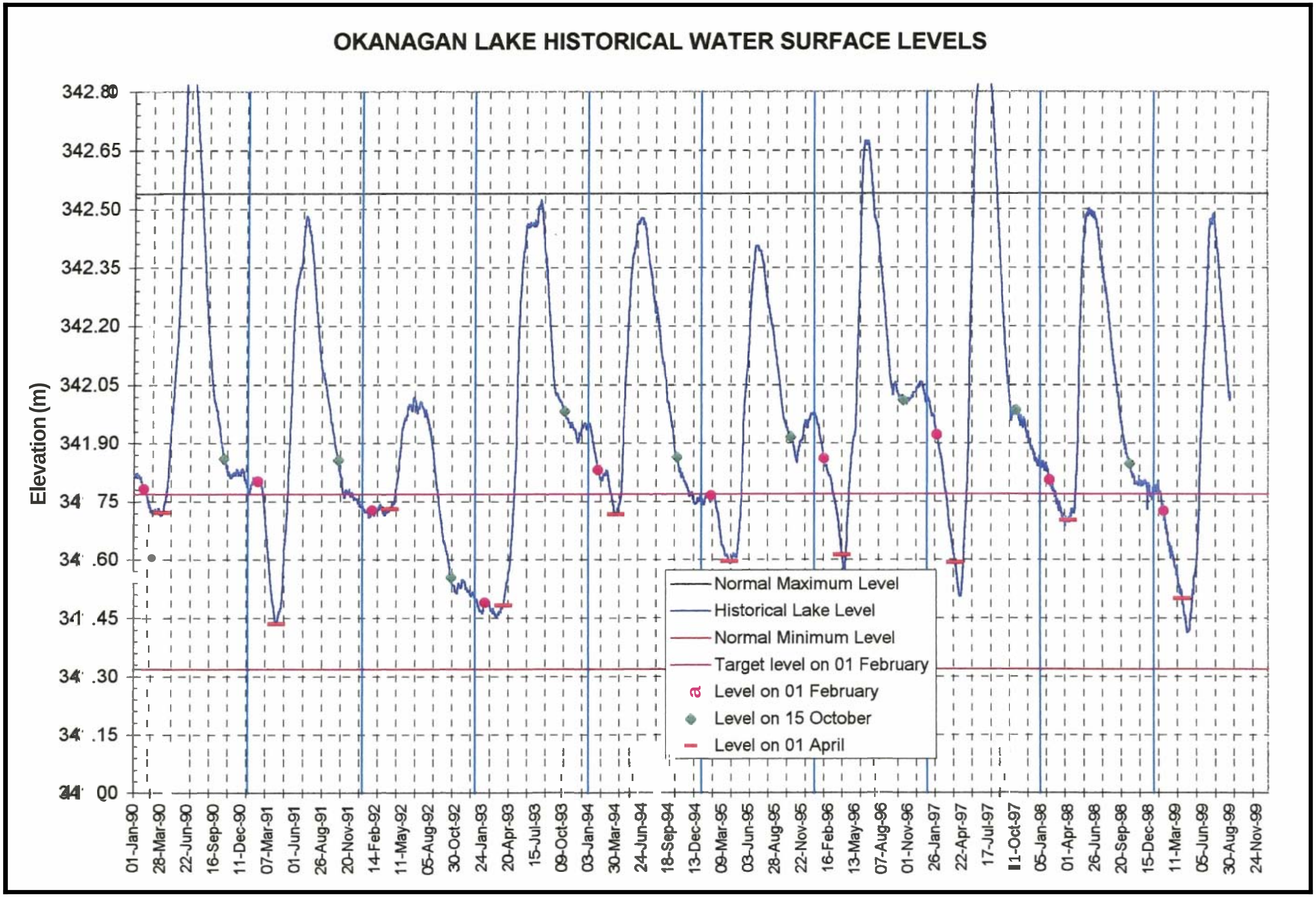
OKANAGAN LAKE HISTORICAL WATER SURFACE LEVELS



Kelowna levels up to 1999.XLS: Level 80s

FIGURE A3 (3 OF 4)

Ward & Associates Ltd.
Water Engineering & Hydrology



Kelowna levels up to 1999.XLS: Level 90s
06-03-2000

FIGURE A3 (4 OF 4)

Ward & Associates Ltd.
Water Engineering & Hydrology

OKANAGAN LAKE HISTORICAL OUTFLOWS AND WATER SURFACE LEVELS

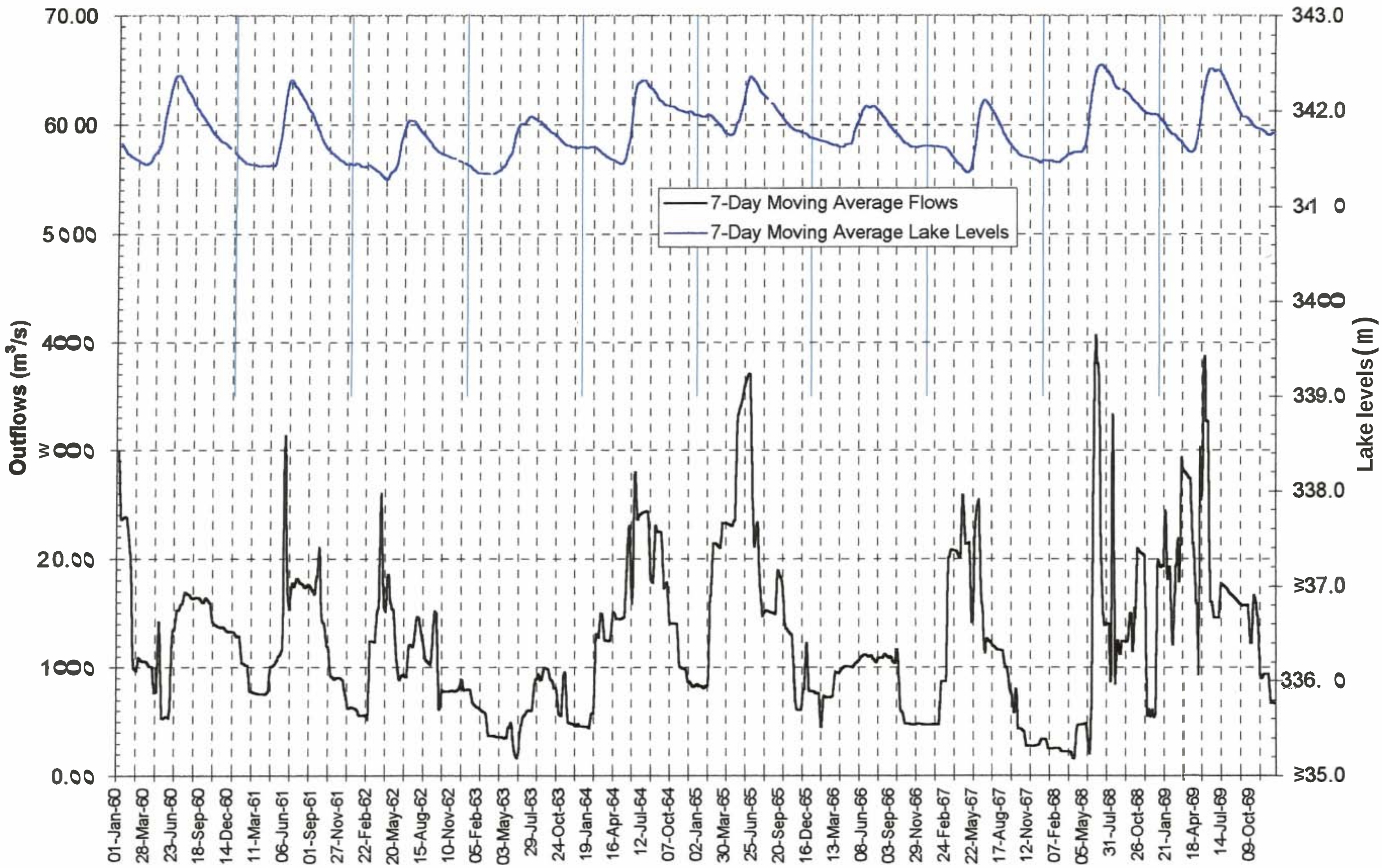
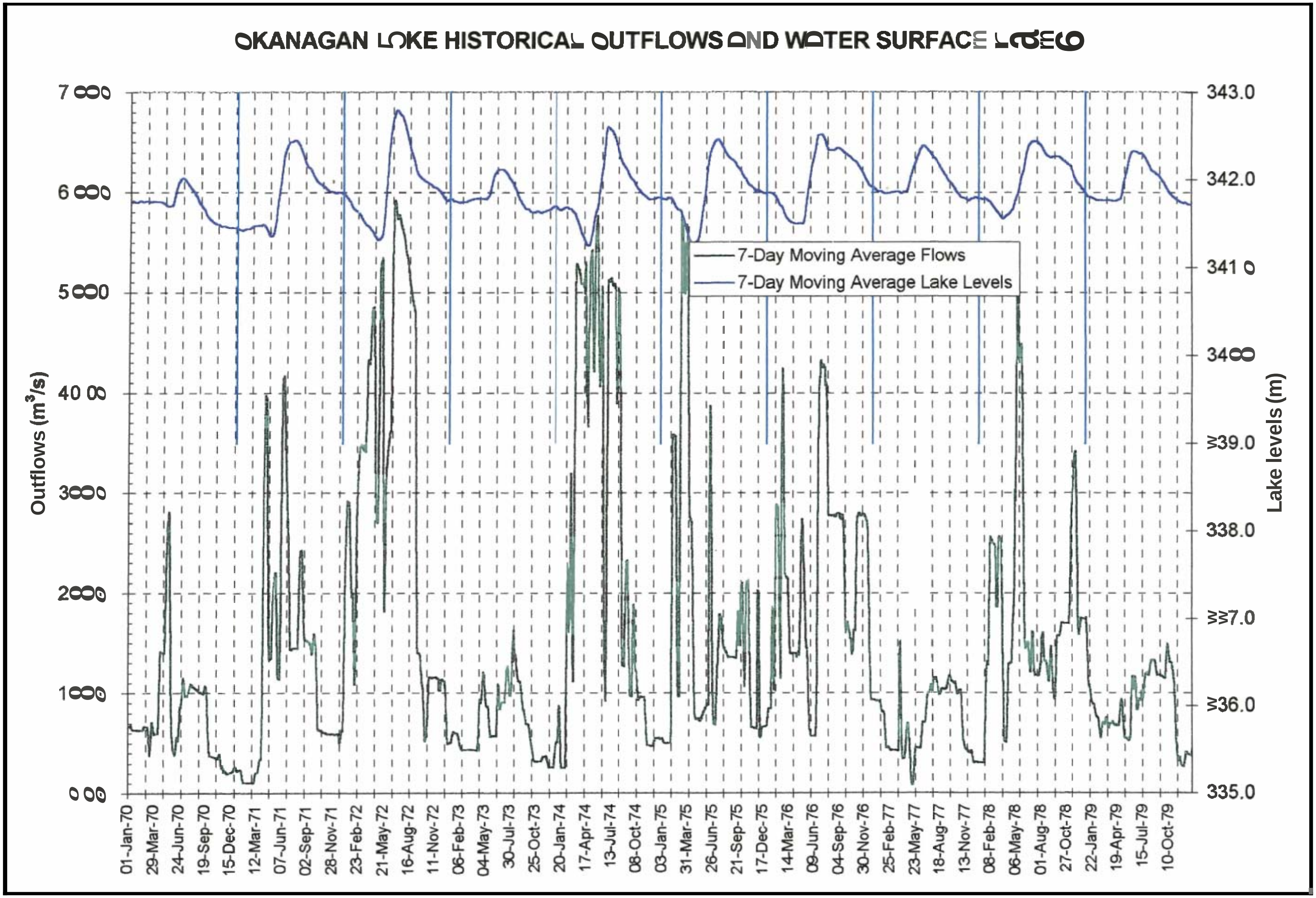


FIGURE A4 (1 OF 4)



7 day Okanagan flows & levels up to 1999.XLS: Chart 70s
06-03-2000

FIGURE A4 (2 OF 4)

Ward & Associates Ltd.
Water Engineering & Hydrology

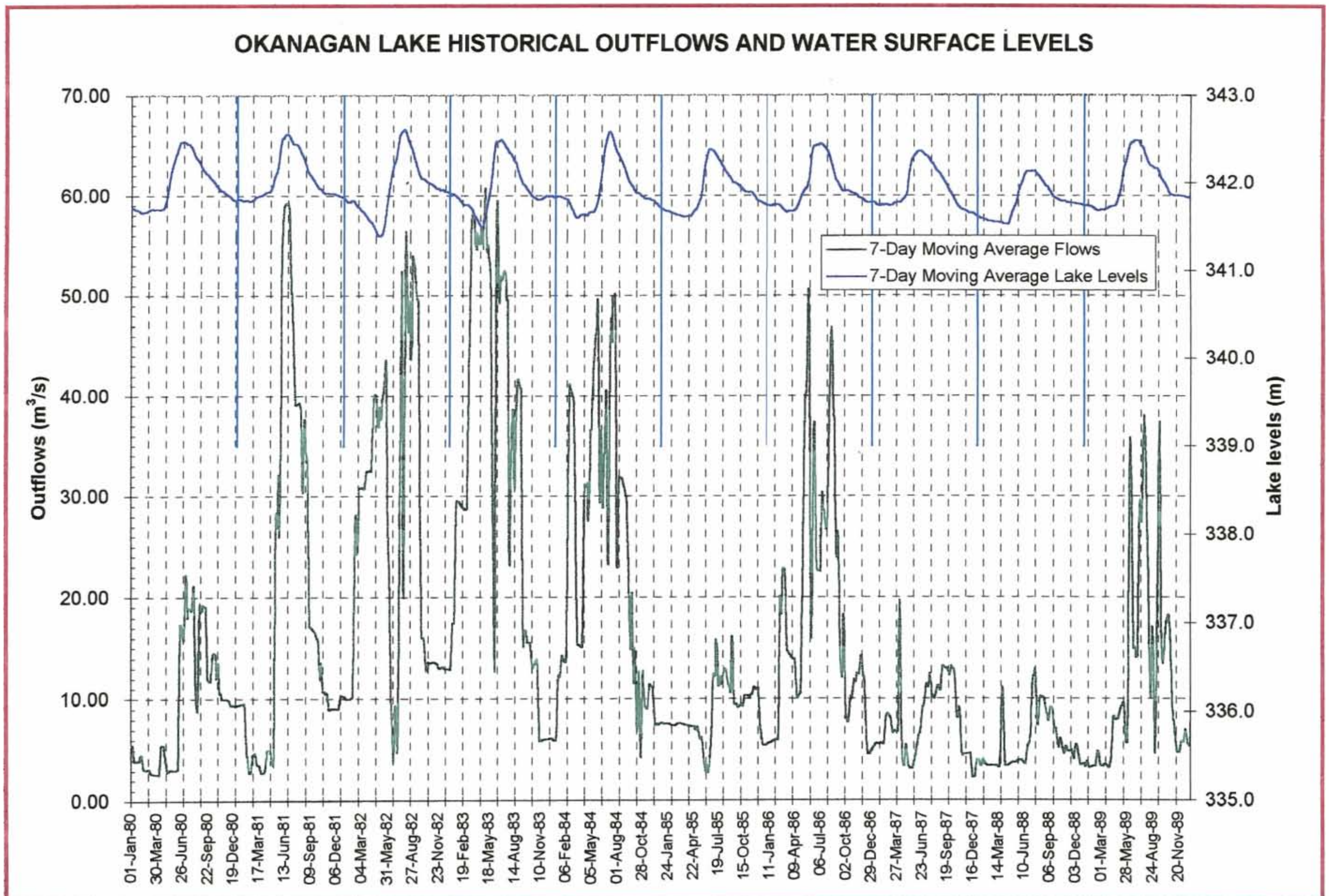
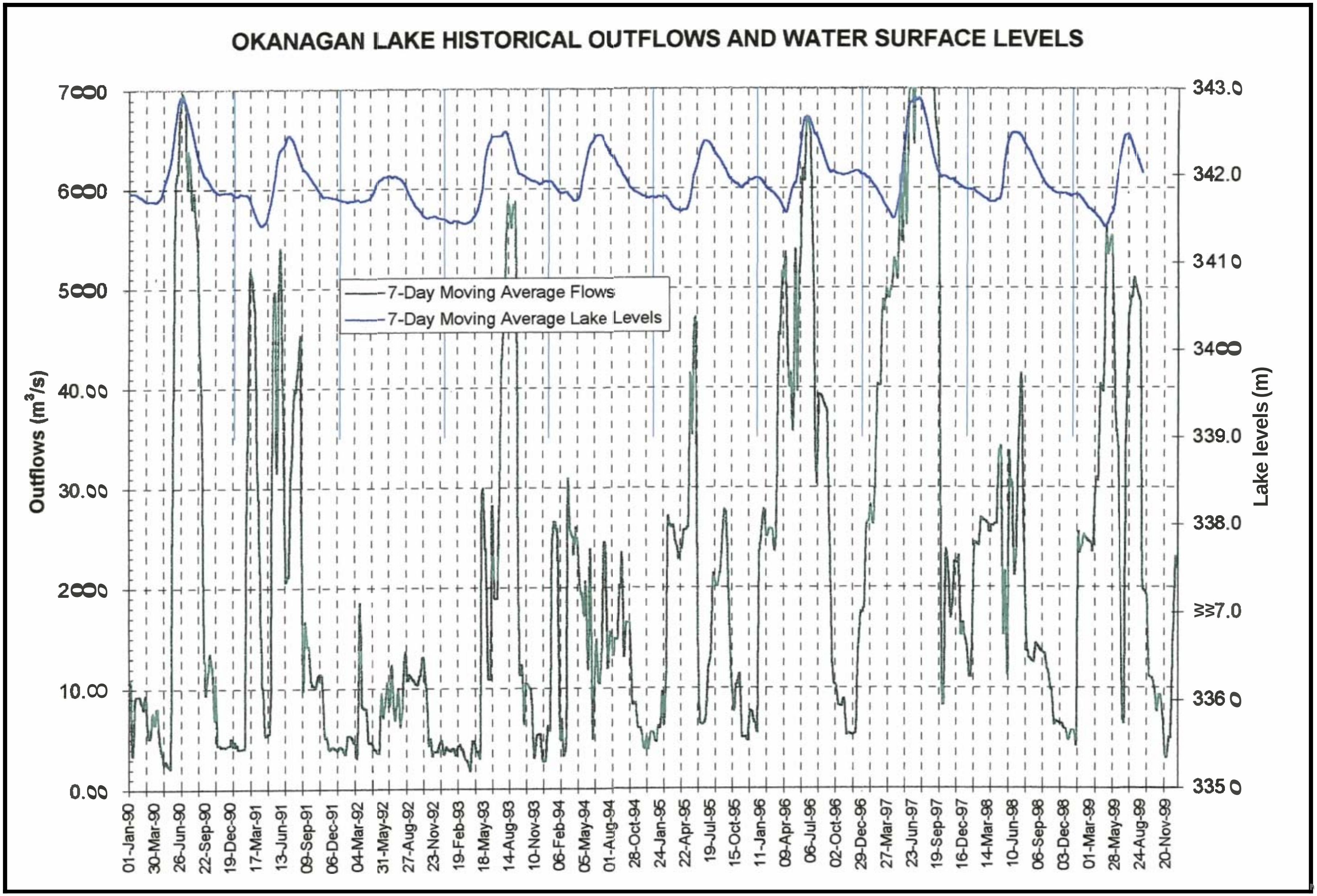


FIGURE A4 (3 OF 4)



7 day Okanagan flows & levels up to 1999.XLS: Chart 90s
06-03-2000

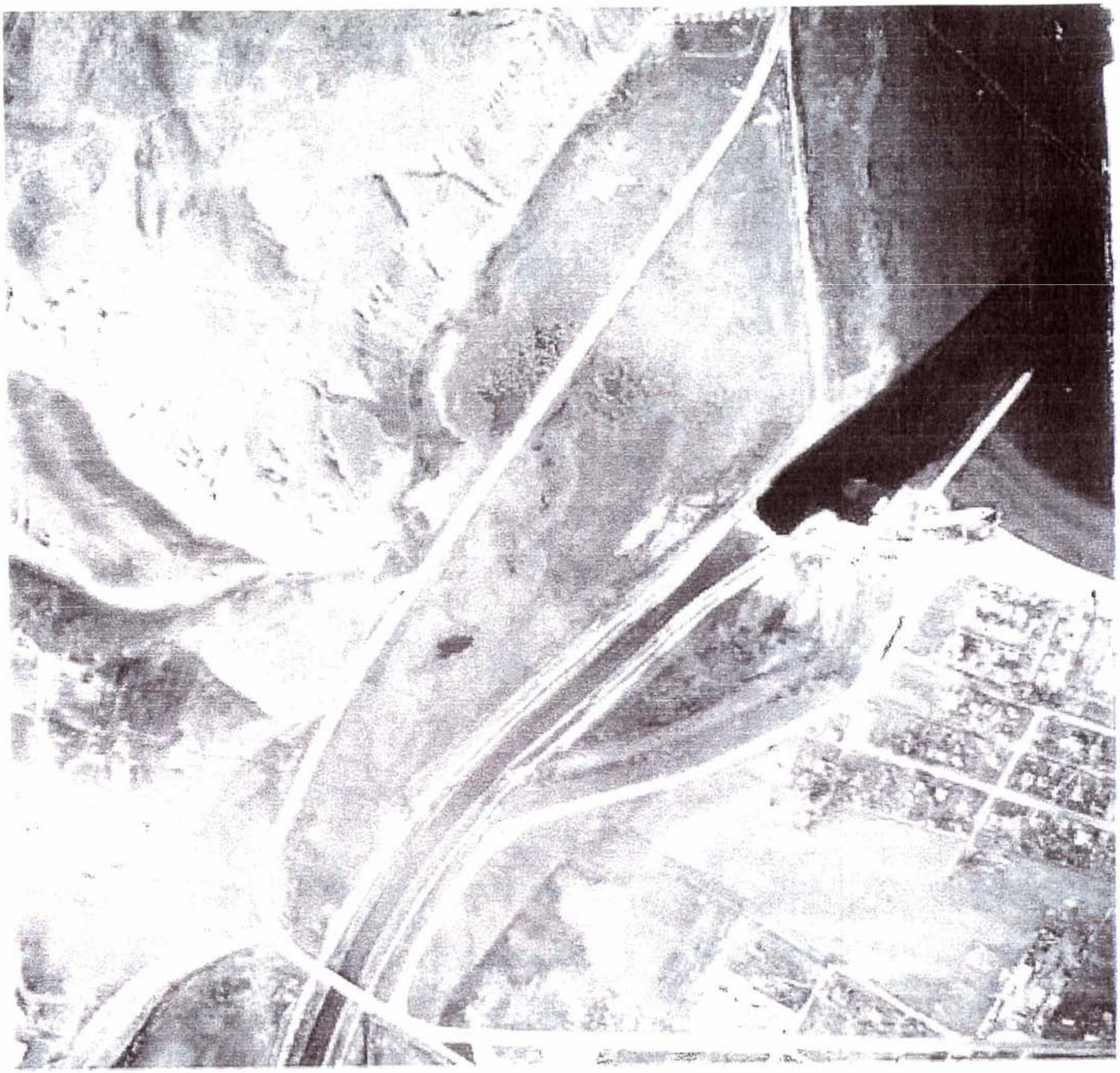
FIGURE A4 (4 OF 4)

Ward & Associates Ltd.
Water Engineering & Hydrology

Appendix B

HISTORICAL AIR PHOTOS
OKANAGAN LAKE AT THE OUTLET

1938 Photo
Approximate scale 1:15,000



1955 Photo

Approximate scale 1:5,000

1977 Photo
Approximate scale 1:12,000

1996 Photo

Approximate scale 1:15,000