CANADA/BRITISH COLUMBIA FLOODPLAIN MAPPING AGREEMENT

PROVINCE OF BRITISH COLUMBIA
Ministry of Environment, Lands and Parks
Water Management Division

A DESIGN BRIEF ON THE FLOODPLAIN MAPPING STUDY OKANAGAN RIVER

An Overview of the Study Undertaken
to Produce Floodplain Mapping for the
Okanagan River from Osoyoos to Penticton

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DESIGN BRIEF ON THE FLOODPLAIN MAPPING STUDY OKANAGAN RIVER

Preface

The purpose of this design brief is to present a description of the methodologies used and results of the study undertaken to produce the floodplain mapping sheets of the Okanagan River, Drawings 89-12, Sheets 1 to 15 from Osoyoos to Penticton.

1. Location

The Okanagan Basin, shown in Figure 1, has a drainage area in south central British Columbia of 7770 square kilometres. A plan and profile of the Okanagan Valley is shown on Figure 2. The portion of the basin referred to as the study area in this design brief includes Osoyoos Lake and the Okanagan River Valley from the international border to Okanagan Lake at Penticton.

The study area is located in the Regional District of Okanagan-Similkameen. The City of Penticton is located at the northern end of the study area between Skaha and Okanagan Lakes. The Town of Oliver is located along the Okanagan River near Tugulnuit Lake as shown on Figure 1. The Village of Osoyoos is located at the southern end of the study area near the international border on Osoyoos Lake.

A summary of basin hydrologic data related to the study area is as follows:

Okanagan River

Annual discharge at Penticton*
(calendar years, 1921 - 1988)
mean - 14.7 m^3/s
maximum (1983) - 31.6 m^3/s
minimum (1931)- 1.6 m^3/s

* (Water Survey of Canada, Gauge 08NM050)

Lakes	Okanagan	Skaha	Osoyoos
Surface area (hectares)	34,075	1,906	1,482 (in B.C.)
Maximum Depth (metres)	244	57	63
Mean Depth (metres)	76	26	15
Normal Operation Range (metres)	341.3 - 342.5	337.6 - 338.2	277.6 - 277.8
Normal Useable Storage (dam^3)	409,000	N/A	N/A
Extreme Operation Range (metres)	340.4-342.5	N/A	277.4 - 278.2
Extreme Useable Storage (dam^3)	716,000	N/A	11,500*
* Drought Condtions only			

2. Background Information

2.1 Okanagan Flood Control System

Following serious flooding in the Okanagan Valley in 1942, a terms of reference in connection with a flood damage protection investigation was prepared by the Joint Board of Engineers appointed by the Government of Canada and the Province of British Columbia. The Report of the Joint Board of Engineers, Okanagan Flood Control, was issued in 1946 (Appendix 1.1). Two of the principal findings of the above noted report were:

1. That a control range of 1.2 metres (4.0 feet) should be provided for Okanagan Lake levels.
2. That a sufficiently large channel for the Okanagan River be provided to ensure that the 1.2 metre control range can be consistently maintained.

The channel design flows adopted by the Board are as follows:

Reach Location	Flow
Okanagan Lake to Shingle Creek	59.5 m^3/s
Shingle Creek to Ellis Creek	68.0 m^3/s
Ellis Creek to Okanagan Falls	76.5 m^3/s
Okanagan Falls to McIntyre (SOLID) Dam	79.3 m^3/s
McIntryre Dam to Osoyoos Lake	96.3 m^3/s

Following the flood of 1948, the Okanagan Flood Control Act (1949) was passed. Under the Act, construction of flood control works began in 1952 and was completed in 1958. The major work included the construction of a new river channel, 3 dams and 17 vertical drop structures and was funded jointly by the Province of British Columbia and the Federal Government. The Flood Control Works are located as shown in Figure 3 and are briefly described below (Appendix 1.10).

The main dam at the outlet of Okanagan Lake (Appendix 2, Photo 17) is used to control the lake between elevations 341.3 and 342.5 metres in normal inflow years. Its five sluice gates are capable of discharging the flood flows in this system (Appendix 3).

The six kilometre channel between Okanagan Lake and Skaha Lake has a design grade of 0.048% and an average flow width of about 28 metres. The water level elevation difference is approximately 4.0 metres between the two lakes. Skaha Lake is controlled between 337.6 and 338.2 metres by the Skaha Lake Dam at Okanagan Falls (Photo 14). The structure is equipped with 4 radial gates with the remaining 6 bays closed by stop logs which allow for increased capacity in an emergency (Appendix 3).

Four vertical drop structures (VDSs No. 14 to 17) are located between Okanagan Falls and Vaseux Lake and control a fall of about 9 metres in the 5 kilometres of excavated channel. The structures consist of low concrete breast walls in which have been built 8 trapezoidal notches. Each drop amounts to approximately 1 metre under flood flows (Photo 12). The channel terminates at Vaseux Lake which is controlled during low flows by the McIntyre (SOLID) Dam (Photo 7). The 1.8 kilometre reach between the dam and Vaseux Lake is subject to weed growth (Eurasian milfoil) which affects channel capacity (Photo 9).

Below the McIntyre Dam, the river channel is "natural" for the next 5.6 kilometres to a point just north of the Town of Oliver near Tugulnuit Lake. From here, the river channel has been excavated to improve flood flow capacity for 18 kilometres where it passes through 13 more vertical drop structures and exits at the northern end of Osoyoos Lake.

In 1958, near design flows were run through the system as a test (Appendix 1.2). From 1963 to 1967, a complete survey of the system was conducted. Many of the corrections recommended in a 1967 report by J.H. Doughty-Davies (Appendix 1.3) were completed by 1974. The report included the production of a large number of drawings including structural details of the 17 vertical drop structures and 3 dams, profiles and cross sections of the Okanagan River from Osoyoos Lake to Okanagan Lake and stage discharge data for the vertical drop structures.

The Okanagan Flood Control System is owned by B. C. Environment and operated from the Regional office in the City of Penticton with flood inflow operation guidance provided by the Hydrology Section staff in Victoria (Appendix 3).

2.2 Okanagan Basin Agreement

The Canada-British Columbia Okanagan Basin Agreement was signed in October, 1969. The objective was "to develop a comprehensive framework plan for the development and management of water resources for the social betterment and economic growth in the Okanagan Basin". The main report and 12 technical supplements (Appendix 1.4) were issued in 1974 including Technical Supplement I, "Water Quantity", which dealt with flooding problems.

Following this, the Okanagan Basin Implementation Agreement was signed on February 9, 1976 between the Governments of Canada and British Columbia to implement the major study recommendations. A report (Appendix 1.5) was issued in September, 1977, outlining work required in the Okanagan flood control system in order to bring it up to the required standard. Another report dated July, 1976 (Appendix 1.6) set out an initial operating plan of the Okanagan Flood Control Project.

2.3 Provincial Flood Damage Reduction Program

In connection with the Flood Damage Reduction Program of the Ministry, the following building elevation requirements were adopted for administrative purposes in the mid-1970's in the study area:

Floodplain Location	Building Floodproofing Elevation Requirements
Okanagan Lake	343.7 metres *
Skaha Lake	339.2 metres *
Vaseux Lake	329.5 metres *
Osoyoos Lake	280.7 metres *
Okanagan River	1.5 metres above design flow level

* G.S.C. Datum, included is an allowance for hydraulic and hydrologic uncertainties.

3. Basis For Present Studies

Under the Okanagan Basin Implementation Agreement, a detailed survey of the Okanagan Flood Control System was undertaken by the Water Management Branch in the summer of 1980. A total of 19 drawings at 1:5000 scale (Appendix 1.7) were produced which provide detailed plans, profiles and 274 cross sections of the 37 kilometre river channel from Osoyoos to Okanagan Lake. A river channel survey was undertaken in 1991 (Appendix 1.12) including the area upstream of VDS No. 13. The results of the survey were compared to the 1980 survey and discussed in Section 5.3

The above-noted survey information, along with 1:5000 scale orthophoto topographic (1 metre contour) mapping based on air photos taken in May 1975, was used in the floodplain mapping study. This mapping was made available as a result of the Provincial Large Scale Mapping Program and used in the study pursuant to Section 7 (3)(h) of the Federal/Provincial Agreement Respecting Floodplain Mapping dated December 3, 1987.

Highwater elevation data obtained by the Special Projects Section staff during the 1990 and 1991 freshet periods was also used in the study for model calibration as outlined in the following sections. These calibration flows were at near design magnitudes and served to verify the flood profile calculations used in the floodplain mapping study.

The B.C. Environment Water Management Division staff located in the City of Penticton under the direction of Mr. B.J. Symonds, P. Eng., reviewed the design brief and provided comments on the floodplain mapping drawings. Mr. M.D. Maxnuk of the Littoral Resources Unit, located in the City of Vernon, provided background information about weed harvesting services on the Okanagan River.

4. Frequency Analysis - Flood Flows and Levels

During 1991, the Hydrologic Modelling Unit, Hydrology Section of B.C. Environment, carried out flow and level frequency analysis for various locations in the study area. The report entitled "Frequency Analysis of Flood Flows and Levels for Okanagan Valley Mainstem System," dated September, 1991(Appendix 3), was prepared by Mr. R.Y. McNeil, P. Eng.

Table 1, below, summarizes the lake levels and flows determined in the McNeil report and used in the floodplain mapping study.

Table 1: Recommended Lake Levels(1) and Flows(2)

LOCATION	Drainage Area (km^2)		Return Period (Years)	
	Total	Local	20	200
Okanagan Lake	6090	-	342.9 m	343.1 m
Okanagan River at Penticton	6090	-	70 m^3/s	92 m^3/s
OK River d/s Ellis & Shingle Cks	6556	466	78m^3/s	92 m^3/s
Skaha Lake	6860	-	338.2 m	338.6 m
OK River at OK Falls	6860	304	87 m^3/s	96 m^3/s
OK River d/s Shuttleworth Ck	6950	90	89 m^3/s	99 m^3/s
Vaseux Lake	N/A	N/A	N/A	N/A
OK River d/s Vaseux Ck	7390	440	100 m^3/s	113 m^3/s
OK River at Oliver	7590	200	105 m^3/s	119 m^3/s
Osoyoos Lake	8100	510	279.3 m	279.9

(1) excluding an allowance for uncertainties

(2) based on daily flows (Appendix 3, Page 4)

5. Hydraulic Analysis

5.1 General

Flood profiles were calculated using the HEC-2 water surface profile computer program, IBM-PC XT Version August 1985, developed by the Hydrologic Engineering Center, United States Army Corps of Engineers in Davis, California. The flood profile calculations assume open water flow conditions.

For the purposes of the backwater studies, the study area was divided into 5 sections as indicated on Figure 3 and outlined below:

Section	Reach Length	Floodplain Mapping Dwg. Numbers	Comments
Osoyoos Lake to Upstream of Tugulnuit Lake	18.0 km	89-12-3 to -7	Confined (1) channel
Tugulnuit Lake to McIntyre Dam	5.6 km	89-12-7 to -8	"Natural" channel
McIntyre Dam to Vaseux Lake	1.8 km	89-12-8	"Natural" channel (Weed growth area)
Vaseux Lake to Skaha Lake Dam	5.0 km	89-12-9 to -10	Confined channel
Skaha Lake to Okanagan Lake	6.0 km	89-12-12 to -13	Confined channel

(1) Okanagan Flood Control System

5.2 Osoyoos Lake

Osoyoos Lake daily levels have been recorded more or less continuously since 1928, just after the original Zosel Dam was built in the Okanogan River downstream of the lake outlet at Oroville, Washington.

The rebuilt Osoyoos Lake Control Structure (Zosel Dam, Photo 1) was constructed and completed by April of 1987. The dam site is 3 kilometres downstream from the outlet of Osoyoos Lake and 15 kilometres south of the United States - Canada border (Appendix 1.11). The dam is used to control normal Osoyoos Lake levels but is drowned out by high flows on the Similkameen River as discussed below.

The highest "unofficial" lake level occurred on May 29,1894, prior to the construction of any storage or control dams on the Okanagan system (Appendix 1.9). The 1894 level of 279.96 metres (GSC datum) is 0.74 metres below the designated level adopted by the Ministry in the mid-1970s. The frequency analysis undertaken by the Hydrology Section (Appendix 3) based on 1930-90 data recommends a 1:200 year Osoyoos Lake level of 279.9 metres. The highest Osoyoos Lake levels, as indicated in Appendix 3, are due to the backwater from flooding on the Similkameen River which joins the Okanogan about 1.6 kilometres south of Zosel Dam. The dam cannot maintain Osoyoos Lake at normal levels during this time.

A designated flood level of 280.7 metres for Osoyoos Lake is 0.8 metres above the 1:200 year (still water) estimated level. Photos 2 and 3 indicate existing buildings in the Village of Osoyoos and the designated flood level.

The allowance of 0.8 metres accounts for meteorological effects (wave and wind setup), wave runup impacts and hydrological uncertainties. Wind and wave setup and wave runup are site specific depending on a number of factors including fetch distance, depth of water, wind direction and roughness and slope of the surface where a breaking wave occurs.

Wind data from Penticton Airport was used for calculating significant wave heights in the study area. The significant wave height represents the average of the highest one third of the waves that occur in a wave field (Appendix 1.15). The winds from the north dominate in the summer and are affected by the local topography in the study area aligned with the general north/south axis of the lakes (Appendix 1.14). Summer waves on Osoyoos Lake would reach a significant height of about 0.6 metres based on a maximum fetch distance of 7 kilometres and a sustained summer wind speed of 50 kilometres per hour.

The elevation reached by wave runup is an important site specific parameter in assessing inundation or overlapping of land or structures by wave action. Under most shoreline conditions, wave runup will be substantially less than the calculated deepwater wave height. (Appendix 1.13). Wind setup for the relatively deep lakes typical of interior British Columbia are substantially smaller than wave runup values (Appendix 1.13 and 1.14).

Given the foregoing, it is recommended that the 280.7 metre designated level of Osoyoos Lake be retained for administrative purposes. As noted on the drawings, properties at or near the lake shore that are exposed to a long fetch may be subject to a special flood hazard relative to wave action.

5.3 Osoyoos Lake to Upstream of Tugulnuit Lake

This reach from Osoyoos Lake to just upstream of Oliver is 18.0 kilometres. The confined width of flow under flood conditions averages approximately 35 metres; dyke crests are approximately 65 metres apart. Drawings 89-12-3 to -7 indicate that the "natural" floodplain width varies from 1300 metres to approximately 120 metres in this area. Evidence of the old "natural" river channel is indicated on the drawings.

The 13 vertical drop structures located in this reach (typically) have a topflow width of 25 metres and the drop in water level across the structure at high flows is approximately 1 metre. Photo 4 indicates Vertical Drop Structure (VDS) No. 3 located in this reach. The weir crest at VDS No. 1 is submerged at high levels on Osoyoos Lake. The water levels upstream of VDSs No. 2 to 13 are controlled by the weir crest elevations.

The available stage discharge relations for the VDSs were used in the study (Appendix 1.3). Calibration of the model in this section was based on the observed levels at 37 cross sections in this reach obtained June 5 and 6, 1990 when recorded flows at the Water Survey of Canada gauge at Oliver varied between 84.4 and 88.1 m^3/s. Manning's "n" values for the channel averaged 0.030 in this reach.

The flood profile for the 1:200 year daily flow of 119 m^3/s was calculated and the results shown on the drawings. In keeping with Ministry practice, an allowance of 0.6 metre was added to the computed water levels to allow for hydraulic and hydrologic uncertainties. The flood levels immediately upstream of the VDSs were used to determine the floodplain limits as indicated on the drawings. Flood levels immediately downstream of the VDSs (approximately one metre lower than the upstream levels) are shown on the drawings for information purposes.

As stated in Section 3, the river channel cross section information obtained in 1991 (Appendix 1.12) was compared with the 1980 survey data in the 1.6 kilometre reach upstream of VDS No. 13. The comparison indicated that there is only minor change in the channel cross sections which would not significantly reduce channel capacity at flood flows.

The crest elevation of the standard dyke on the reach from Osoyoos Lake to upstream of Tugulnuit Lake averages 1.6 metres above the computed 1:200 year flood level. Flood channel capacity (ignoring scouring and erosion concerns) is greatly in excess of the 119 m^3/s flow in this reach. Photo 5 shows maintenance repairs underway (October 1991) at VDS No. 6.

A comparison was made with the designated flood level (freeboard included) obtained in this reach and the "rule of thumb" building floodproofing elevation requirement adopted by the Ministry (Section 2.3) in the mid-1970's. The 1991 designated flood levels averaged 0.5 metres below the previously adopted levels.

Sensitivity studies indicated that a flow increase of 40% above the 1:200 year flow results in an average level increase of 0.6 metres. Manning's "n" value increases of 40% results in a maximum rise of 0.5 metres.

5.4 Tugulnuit Lake to McIntyre Dam

This 5.6 kilometre reach is not confined by standard dykes and has a floodplain width which varies from 40 metres to 800 metres as indicated on Drawings 89-12-7 and -8. There are no drop structures in this reach. Photo 6 indicates the river channel immediately downstream of McIntyre Dam.

The model was calibrated to match water level data (5 Sections) obtained on June 5, 1990, when flows were 88 m^3/s in this reach. Manning's channel "n" values averaged 0.035 in this reach.

The flood profile was calculated for the 1:200 year daily flow (109 m^3/s to 113 m^3/s) in this reach and the results (0.6 m allowance added in accordance with the Ministry practice) shown on floodplain mapping sheets 7 and 8. Sensitivity studies indicated that a 40% flow increase over the 1:200 year flood event will result in an average level increase of 0.24 metres. Similarly, a Manning's "n" value increase of 40% results in an average level increase of 0.28 metres in this reach.

5.5 McIntyre Dam to Vaseux Lake

The 1.8 kilometre reach between the McIntyre Dam and Vaseux Lake is shown on Drawing 89-12-8. This reach is affected by weed growth which hinders the flow capacity of the main channel of the river as noted in Appendix 3.

The model was calibrated to match levels obtained on June 20th of 1991, during which time flows were 44 m^3/s. Manning's channel "n" for the reach averaged 0.030 based on the June 1991 data. Studies undertaken in 1981, based on observed water levels for flows of 45 m^3/s in the reach indicated that Manning's "n" values increased by 30% (from 0.032-0.040 to 0.042-0.052) between June 16 and July 21, 1981, as a result of weed growth (Appendix 1.8).

The maximum desirable level of Vaseux Lake is 328.0 metres and the minimum McIntyre Dam forebay level required for diversion purposes is 327.1 metres, according to the 1981 backwater study data. Weed harvesting is undertaken under the direction of the Ministry in this reach during high flow periods in an attempt to reduce Vaseux Lake levels (Photo 9). Flows are temporarily reduced to allow harvesting. McIntyre Dam and the irrigation intake works are shown in Photos 7 and 8 respectively. Photo 11 indicates existing homesites at the southern end of Vaseux Lake.

Given the uncertainties with respect to the effect of weed growth on Manning's "n" values and the demonstrated need for an ongoing weed harvesting program during high flow periods, a relatively high (ie. conservative) Manning's "n" value of 0.046 to 0.057 was used to determine the 1:200 year flood levels in the reach between the McIntyre Dam and Vaseux Lake.

For a channel flow of 109 m^3/s, the lake level was determined to be 328.9 metres or 0.6 metres below the designated flood level of 329.5 metres established in the mid-1970s.

Waves on Vaseux Lake would reach a significant height of about 0.6 metres based on a maximum fetch distance of 4.0 kilometres and a sustained wind of 50 kilometres per hour. As discussed in Section 5.2, meteorogical effects are site specific and wave runup will be substantially lower than deepwater wave heights under most shoreline conditions.

It is recommended that the designated flood level of 329.5 metres for Vaseux Lake be retained for administrative purposes. As noted on Drawings 89-12-8 and -9, properties at or near the lakeshore that are exposed to a long fetch may be subject to a special flood hazard related to wave action.

5.6 Vaseux Lake to Skaha Lake Dam

This 5.0 kilometre reach from Vaseux Lake to Skaha Lake Dam is confined by standard dykes as shown on Drawings 89-12-09 and -10. The natural floodplain width varies from 500 metres at the northern end of Vaseux Lake to approximately 40 metres in width immediately downstream of Skaha Lake Dam as shown in Photo 13.

There are 39 channel cross sections in this reach which contains 4 VDSs located as indicated on Drawings 89-12-09 and -10. Photo 12 shows VDS No. 17 in this reach. Water level upstream of the VDSs is controlled by the weir crest elevation. As stated in Section 5.3, the available stage discharge relations for the VDSs were used in the study (Appendix 1.3). The model was calibrated to match 14 observed water levels obtained on June 5, 1990. Mannings "n" values for the channel were computed and averaged 0.030 for the recorded flow of 66 m^3/s at Okanagan Falls.

The flood profile was calculated for the 1:200 year flow of 96 m^3/s. The results (allowance of 0.6 m included) are shown on the above-noted Drawings. Sensitivity studies indicated that a flow increase of 40% over the 1:200 year flow results in an average level increase of 0.6 metres. Similarly, Manning's "n" increases of 40% result in a level rise of 0.5 metres once the influence of the vertical drop structures is overcome.

5.7 Skaha Lake to Okanagan Lake Dam

The designated flood level established by the Ministry in the mid-1970's for Skaha Lake is 339.2 metres. The recommended 1:200 year lake level (Appendix 3), based on a flow of 96 m^3/s, is 0.65 metres below the designated flood level. Waves on Skaha Lake would reach a significant height of 0.55 metres based on a maximum fetch of 9.0 kilometres and a sustained wind of 50 kilometres per hour. As discussed in Section 5.2, meteorological effects are site specific and wave runup will be substantially lower than deep water wave heights under most shoreline conditions.

Many of the floodplain properties on the north shore of Skaha Lake in the City of Penticton are protected from the brunt of wave action by existing shoreline roads. It is recommended that the designated flood level of 339.2 metres for Skaha Lake be retained for administrative purposes.

This 6.0 kilometre reach which flows through the City of Penticton is confined by standard dykes as indicated on Drawings 89-12-13 and -15. Photo 16 is a view of the Okanagan River channel near the Shingle Creek confluence. There are 45 channel cross sections in the reach and the model was calibrated to match high flow data obtained in June of 1990.

The flood profile for the 1:200 year daily flow of 92 m^3/s was calculated and the results (0.6 m allowance included) shown on the floodplain mapping sheets. The flood channel capacity greatly exceeds the 1:200 year flow estimate. Operational concerns relate to long-term flow releases causing channel scouring and erosion around the control structure. The dyke crest elevation averages 1.6 metres above the 1:200 year flood level in the reach.

5.8 Okanagan Lake

Photo 16 shows the shoreline of Okanagan Lake east of the dam. The highest recorded Okanagan Lake level occurred in 1948 and reached 343.13 metres (Appendix 3). The 1972 flood resulted in a maximum net inflow (April to July) of record of 565,510 dam^3. The maximum lake level was 342.8 metres and the lake was within 0.3 metres of this level for a period of 58 days. Applying the flood control operating sequence adopted in 1972 to the estimated 1:200 year net inflow of 622,800 dam^3 (Appendix 1.4) results in a lake level of approximately 343.05 metres. The designated flood level of 343.7 metres was adopted by the Ministry in the mid-1970s.

The flood frequency analysis undertaken in 1991, (Appendix 3) results in an estimated 1:200 year level of 342.9 metres based on modern (1951-1990) operation data. Analysis of historical (1921-1990) lake level data indicates a 1:200 year lake level 0.3 metres higher. The difference may well be as a result of the increased discharge capacity of the dam at the outlet of Okanagan lake (Photo 17) and the ability to forecast inflow values more accurately.

Many of the properties on the southern end of Okanagan Lake that are exposed to a long fetch in the City of Penticton are protected from the brunt of wave action by Lakeshore Drive (Photo 18). The design of the Okanagan Lake control dam results in a flood level drop of approximately 2 metres in the flood control channel immediately downstream of the structure. As noted on Dwg. 89-12-15, land located south of Lakeshore Drive and at elevations below the Okanagan Lake flood level may be subject to surface drainage or seepage problems during the freshet period.

During 1990, the maximum lake level recorded was 342.94 metres and the lake was within 0.3 metres of this level for a 54-day period (June 6 to July 30). Concern about high lake levels and potential wave action problems resulted in various properties along the lake receiving sandbag protection. Included in these emergency procedures was the recently developed retirement homesites on the Indian Reserve lands located west of Okanagan Lake dam (Dwg. 89-12-15 is based on 1975 air photos and does not show the recent development noted in the foregoing).

The prevailing dominant wind speed was from the north and averaged between 7.5 and 8.5 kilometres per hour at Penticton airport during the 1990 high lake level period. Problems related to wave action were not considered severe. Maximum hourly mean wind speed from the north was 26 kilometres per hour on July 19, 1990, when the lake level was 342.8 metres or 0.8 metres below the designated flood level. Maximum wind gust from the north was 44 kilometres per hour on July 15, 1990.

Waves on Okanagan Lake would reach a significant height of 0.8 metres based on a maximum fetch of 18 kilometres and a sustained wind speed of 50 kilometres per hour. As outlined in Section 5.2 wave runup is site specific and may be substantially lower under typical shoreline conditions.

Based on the foregoing, it is recommended that the designated flood level of 343.7 metres on the Okanagan Lake be retained for administrative purposes. Properties at or near the lakeshore that are exposed to a long fetch may be subject to a special flood hazard related to wave action, as noted on the Drawings.

6. Floodplain Mapping

6.1 General

The flood levels determined in the study were used to delineate the floodplain limits onto the existing one metre contour orthophoto mapping of the study area. The floodplain mapping for the Okanagan River, Drawing 89-12 sheets 1 to 15, indicates the location of the 17 vertical drop structures, 3 control dams, computed flood levels, and the floodplain limits.

As noted in Section 3, the existing contour mapping was made available as a result of the Provincial Large Scale Mapping Program and used in this study under the terms of the December 3, 1987 Agreement. It was noted during the study that there have been significant transportation routes and subdivisions developed in and about the City of Penticton (Dwgs. 89-12-14 and 15) involving landfilling in the floodplain. Consideration should be given to selectively updating the existing contour mapping to reflect these development activities.

From the foregoing, it has been concluded that the mapping sheets should be interim designated at this time.

Flood levels drop approximately 2 metres through the sluice gates of the major storage dam on the Okanagan Flood Control System (Photo 17) located at the outlet of Okanagan Lake. Properties located south of Lakeshore Drive are protected from the brunt of wave action during high lake levels as noted in Section 5.8.

Drawing 89-12-15 indicates that the floodplain limit of Okanagan Lake is assumed to extend east from the control dam along Lakeshore Drive. As noted on the drawing, land located south of Lakeshore Drive at elevations below the Okanagan Lake Flood Levels (343.7 metres) may be subject to surface drainage or ground seepage problems during periods of high lake levels.

The floodplain limits south of Lakeshore Drive are based on the flood levels in the flood control channel which connects Okanagan and Skaha Lakes. In keeping with Ministry practice, the floodplain limits extend beyond the existing dykes. In the event of a dyke failure, flood levels are dependant on site specific conditions such as road crest elevations and the extent of the dyke breach. For this reason, the flood level isograms have been dashed across the floodplain in the dyked reaches.

The flood levels immediately upstream of the VDSs were used to determine the floodplain limits. Elevations immediately downstream of the structures are shown on the drawings for information purposes.

The designated flood levels shown for the major lakes in the study area include an allowance for meteorological effects and hydrological uncertainties. As noted in the drawings, wave action and related erosion at high lake levels may present a special flood hazard depending on site specific conditions.

6.2 Tributary Alluvial Fans

Tributary watercourses are not part of this floodplain mapping study. It was recognized that a potential for flooding problems exists in several of the tributary alluvial fans in the study area. Following is a list of fans noted on the floodplain drawings which are known to be active based on field observations and Ministry staff experience.

Testalinden Creek	Sheets 4 and 5
Wolfcub Creek	Sheet 6
Vaseux Creek	Sheets 7 and 8
Shuttleworth Creek	Sheet 10
Shingle Creek	Sheet 14
Ellis Creek	Sheet 14
Penticton Creek	Sheet 15

As noted in Photos 19 to 24, control structures such as dykes, berms, concrete channels and sediment stilling basins have been located along some of these tributary watercourses.

The floodplain limits of the above-noted alluvial fans have not been determined in this study. In keeping with Ministry practice, a note has been placed on the drawings concerning the special flood hazards potential related to channel avulsion and erosion in these fan areas.

7. Recommendations

1. Pursuant to the terms of the Canada/British Columbia Floodplain Mapping Agreement, it is recommended that the floodplains delineated on Drawing 89 -12, sheets 1 to 15, be interim designated.

2. The floodplain mapping may be used for administrative purposes related to the preparation of hazard map schedules for official plans; floodproofing requirements in zoning and building bylaws; and the identification of floodplain lands by Subdivision Approving Officers.

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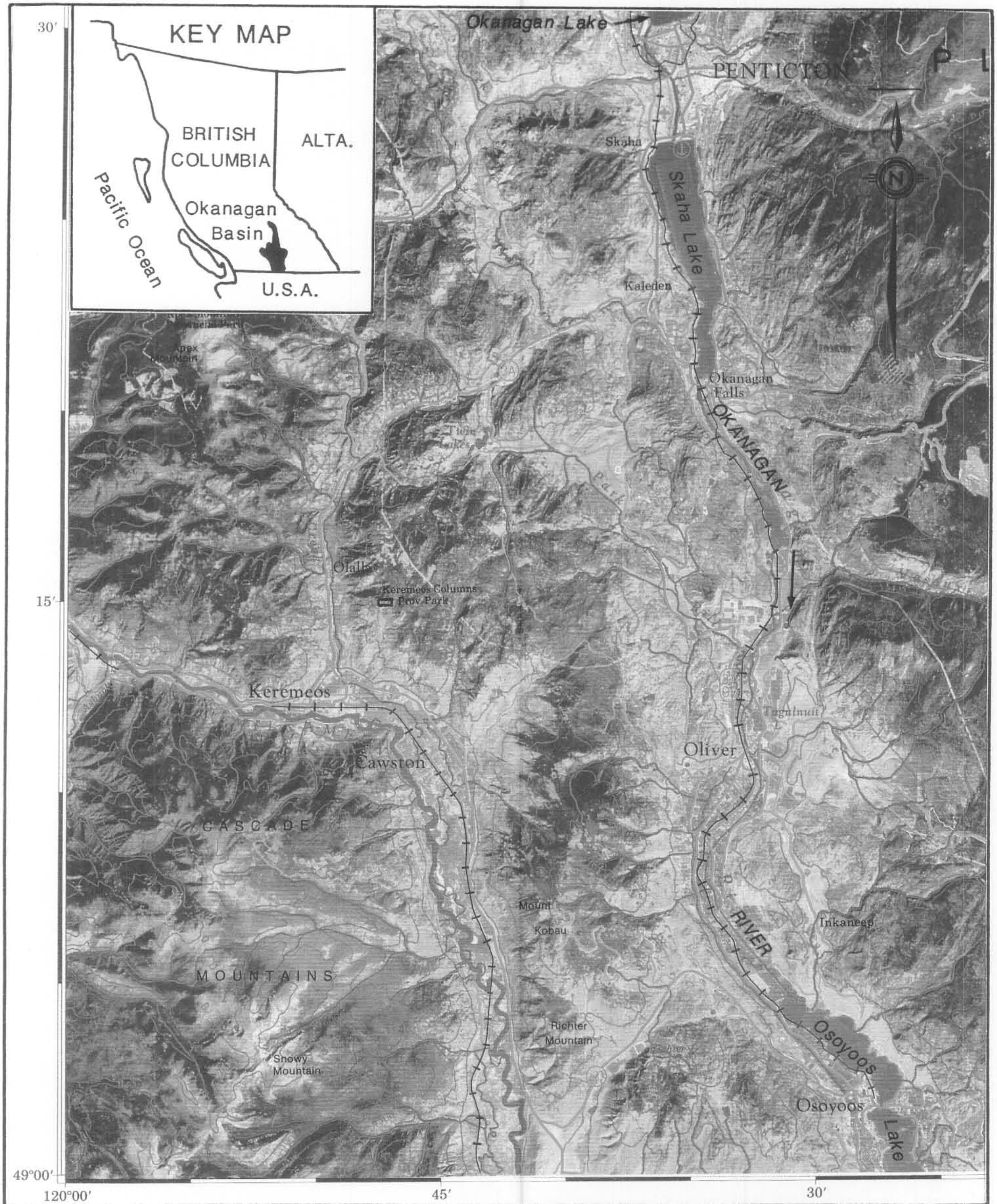
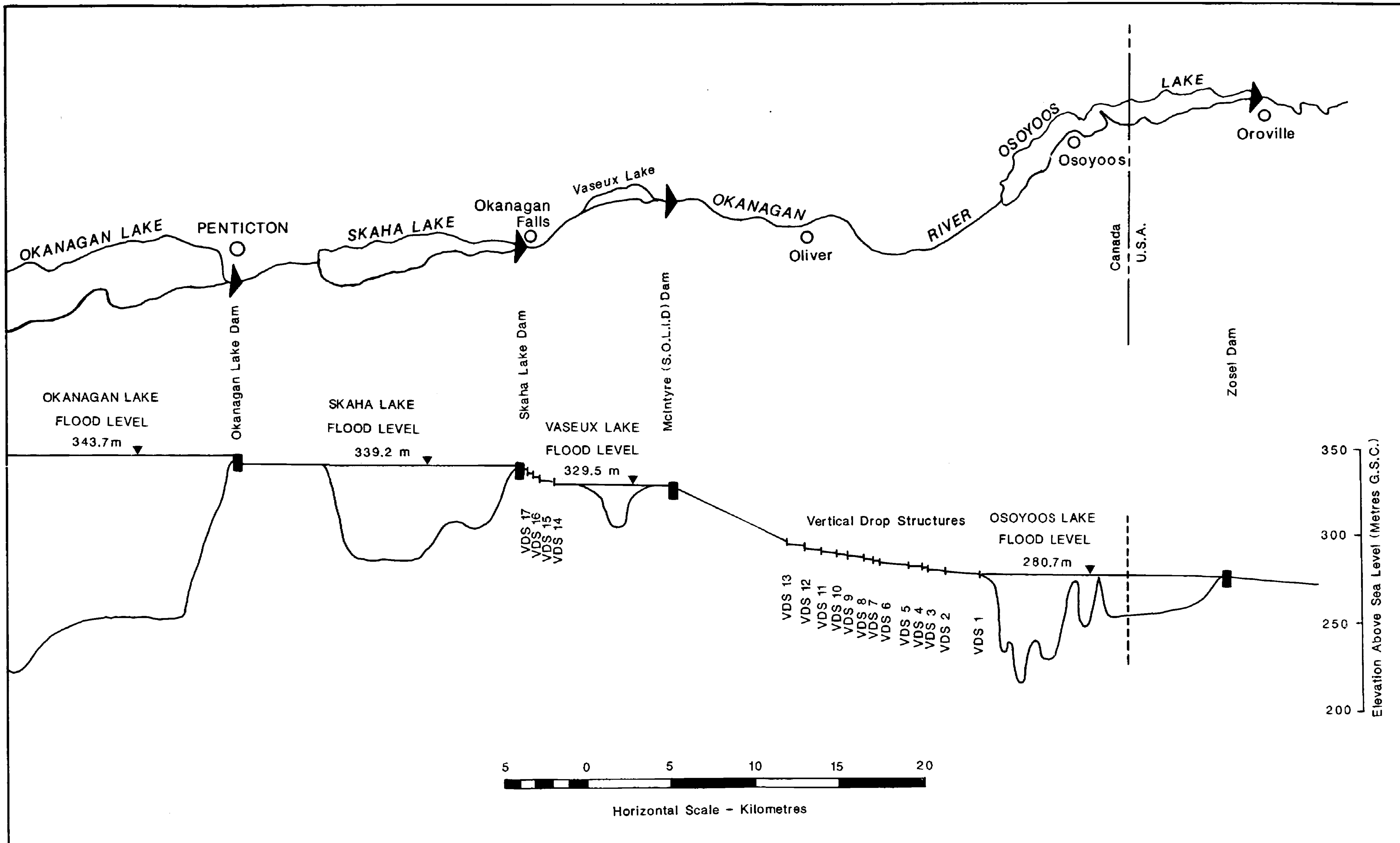


Province of British Columbia
Ministry of Environment
WATER MANAGEMENT BRANCH

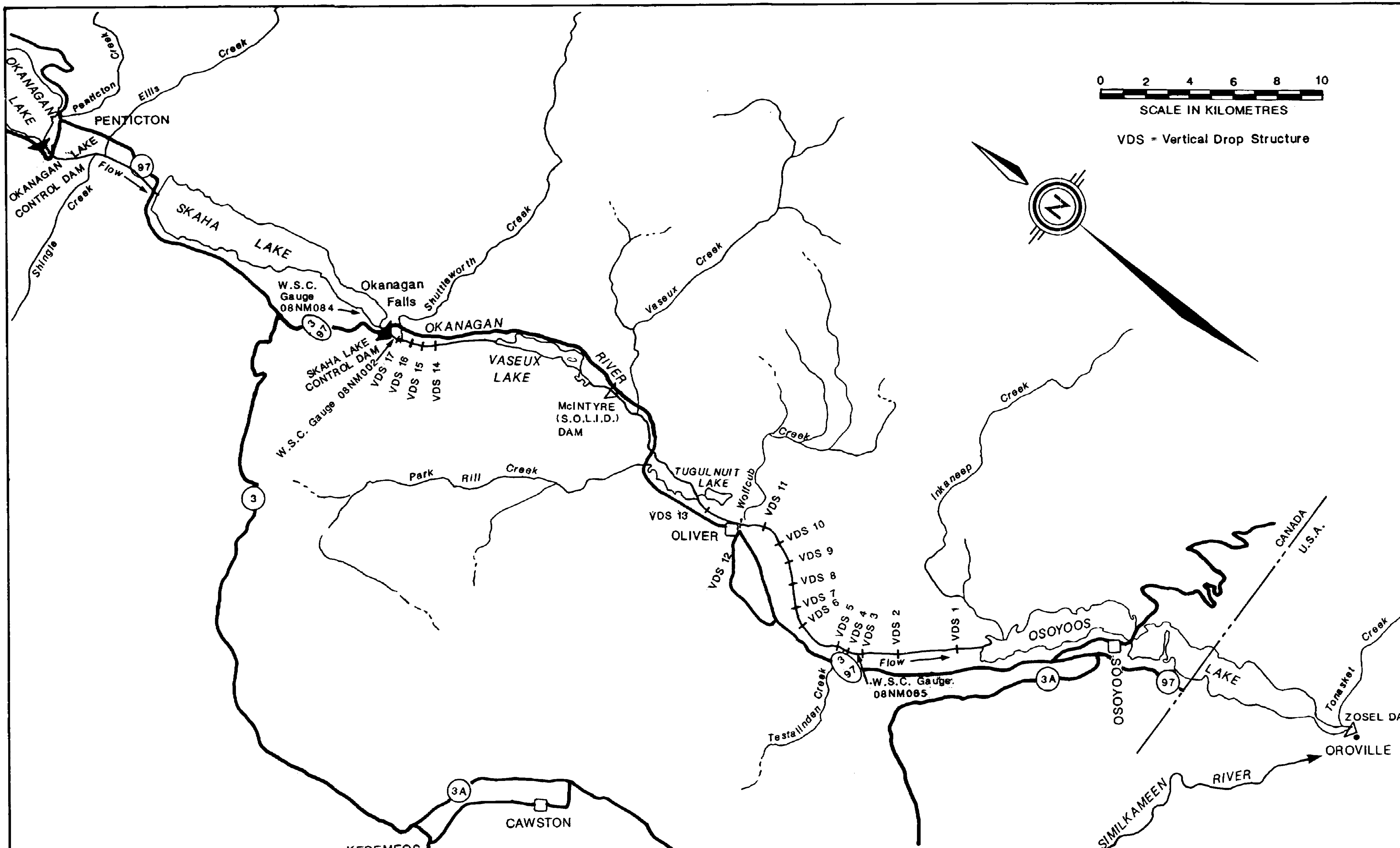
TO ACCOMPANY A DESIGN BRIEF ON THE

FLOODPLAIN MAPPING STUDY
OKANAGAN RIVER
STUDY AREA LOCATION

SCALE: VERT. ____ HOR. 1 : 250,000	DATE DEC. 1991	R.W. NICHOLS ENGINEER FILE No. 31-0000-S.3 DWG. No. FIGURE 1



	Province of British Columbia Ministry of Environment Water Management Branch	To Accompany a Design Brief on the FLOODPLAIN MAPPING STUDY OKANAGAN RIVER PLAN AND PROFILE	SCALE: VERT. AS SHOWN HOR. AS SHOWN R.W. Nichols ENGINEER FILE No. 31-0000-S.3 DWG No. FIGURE 2	DATE DEC. 1991



Province of British Columbia
Ministry of Environment
Water Management Branch

TO ACCOMPANY A DESIGN BRIEF ON

FLOODPLAIN MAPPING STUDY
OKANAGAN RIVER
FLOOD CONTROL WORKS

SCALE: VERT. ____
HOR. AS SHOWN

DATE
DEC. 1991

R.W. NICHOLS ENGINEER

FILE No. 31-0000-S.3 DWG No. FIGURE 3

APPENDIX 1

DETAILED INFORMATION SOURCES
OKANAGAN RIVER

No.	SOURCE	CONTENTS
1.	"Report on the Joint Board of Engineers, Okanagan Flood Control." Volume One - Text; Volume Two - Maps, Plans, etc., 1946., Water Resources Service Library (WRSL)Ref. 591	Results of comprehensive investigations into flood damage protection in the Okanagan drainage area in British Columbia.
2.	"The Testing of the Okanagan Flood Control Channel, April 1958," interim and final reports - Goodyear, WRSL Ref. Nos. 581, 582.	Reports and recommendations regarding deficiencies in the Okanagan Flood Control Channel.
3.	"Okanagan Flood Control Works, 1963 Survey, Revised 1967," J. H. Doughty-Davies, Senior Hydraulic Engineer, February 1967, WRSL File: 0265505, Volumes I to III.	Report recommended rehabilitation works and operating procedures for the Okanagan Flood Control System.
4.	Canada-British Columbia Okanagan Basin Agreement, Final Publication, 1974. 1. Summary Report 2 Main Report 3 Technical Supplements	Report on a 4-year study of water resource management in the Okanagan Basin 1970-74.
5.	"Proposed Rehabilitation of Okanagan River Channel Works," Projects 4 to 7, Water Investigation Branch, File: 0281792, September, 1977.	A study undertaken to determine detailed modifications and repairs required to the Okanagan Flood Control System.
6.	"Okanagan Lake and River Operating Plan," July, 1976, Water Investigations Branch, Files: 0281792-D, 0317580 Gen.	An operating plan set out in accordance with the Canada-British Columbia O.B.I.A. - Paragraph 13(b).
7.	Project No. 79 O.B.I.P. - 2(80), Surveys Section, Water Management Branch, Drawings A5221 - Sheets 1 to 19.	Detailed survey of the Okanagan Flood Control System in 1979/80.
8.	Memo to Mr. A. Brown, P.Eng. from Mr. R.W. Nichols, P.Eng., Ministry of Environment "HEC-2 Program, Head Loss Vaseux Lake to SOLID Dam," July 27, 1981.	Comparison of the effect of weed growth on Manning's "n" values.

Detailed Information Sources - Okanagan River
continued

NO.	SOURCE	COMMENTS
9.	"Osoyoos Flood Protection Information," April, 1975, WRS Report; Province of B.C., WRSL Ref. No. 2595.	Under the OBIA Recommendations 14(V), a report prepared outlining emergency protection measures to Osoyoos Lake area residents.
10.	"Control of the Okanagan River Floods in British Columbia," T.A.J. Leach, October 20, 1961, WRSL Ref. No. 595.	Description of the Okanagan River Flood Control System in British Columbia.
11.	"Zosel Dam Operating Procedures Plan," State of Washington, Dept. of Ecology, July, 1990.	Details on the Zosel Dam in Washington State.
12.	Project No. 9117E041 - Okanagan River Channel Survey, 1991, Technical Support Section, Water Management Branch.	Includes channel cross sections at the vertical drop structures and the channel upstream of VDS No. 13 for a distance of 1.6 km.
13.	Floodplain Mapping Study, Slocan River, British Columbia, Design Brief, Northwest Hydraulic Consultants Limited, February, 1989.	Includes an assessment of the effects of wave heights on predicted Slocan Lake levels.
14.	A Design Brief on the Floodplain Mapping Study, Christina Lake, R. W. Nichols, Senior Hydraulic Engineer, Special Projects Section, November, 1990.	A description of the methodologies used and the results of the study undertaken to delineate the floodplain of Christina Lake.
15.	Shore Protection Manual, Volumes 1 to 3, U.S. Army Coastal Engineering Research Center, 1984.	An outline of research and development related to design and engineering of coastal structures.

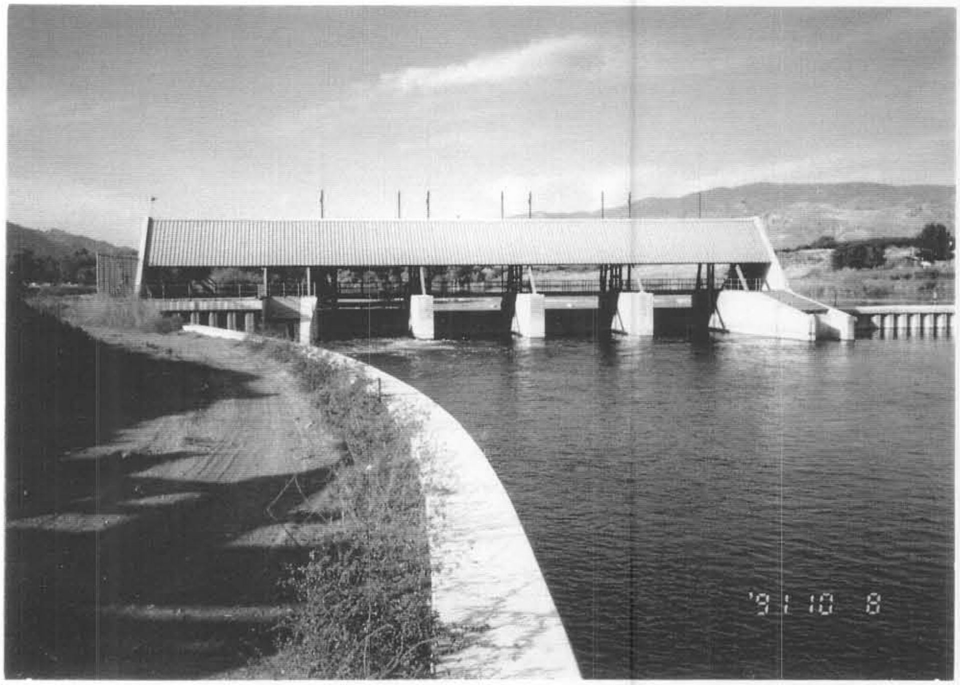


Photo 1

Zosel Dam, located at Oroville, Washington is used to control normal Osoyoos Lake levels.

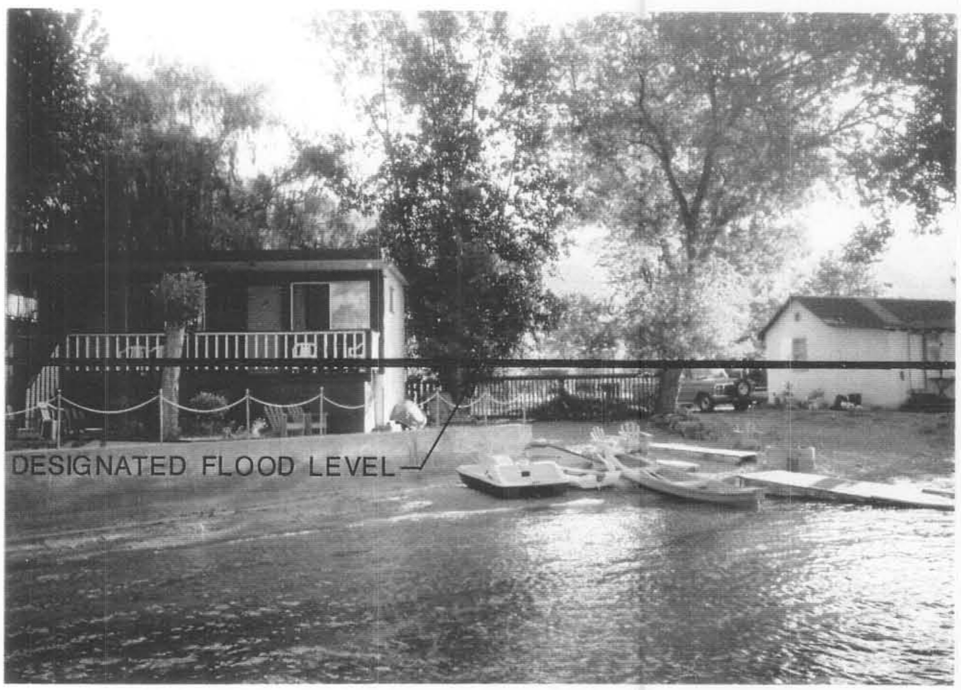


Photo 2

Home and motel in the Village of Osoyoos. Osoyoos Lake designated flood level indicated on photo.
[Dwg. 89-12-1]

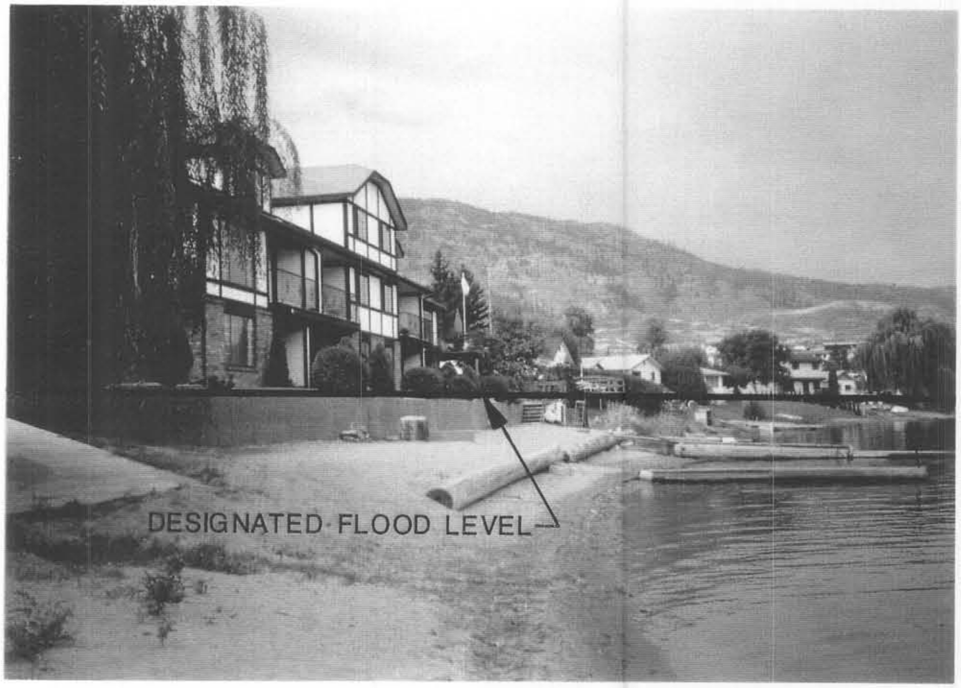


Photo 3

Osoyoos Lake designated flood level indicated on photo. Multiple dwelling building in left of photo is floodproofed. [Dwg 89-12-1]

Photo 4

Vertical Drop Structure (VDS). No. 3 located upstream of Osoyoos Lake in dyked channel. [Dwg 89-12-4]

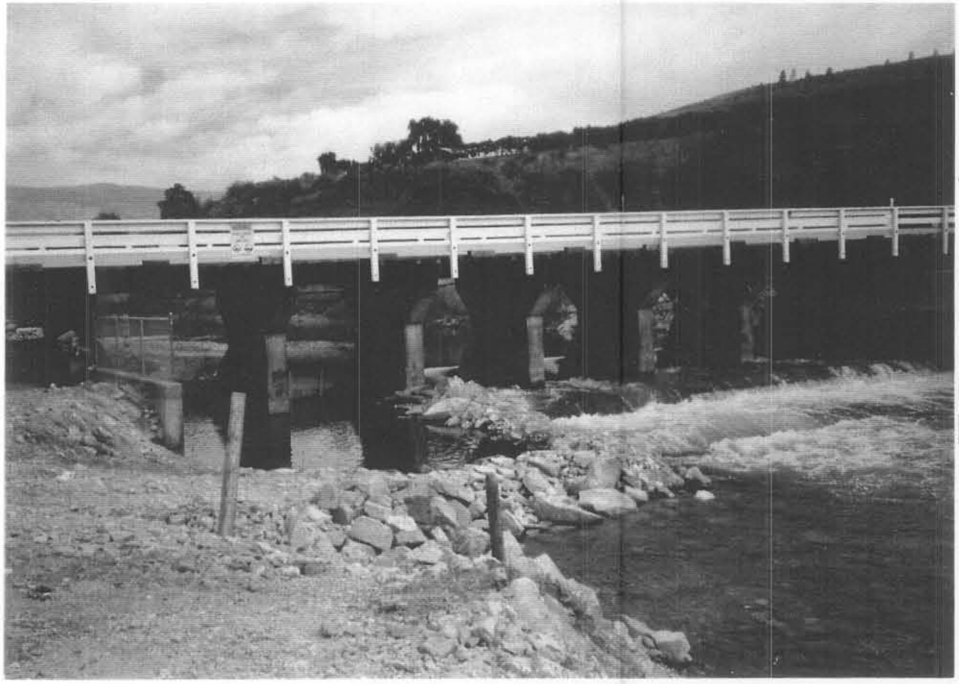


Photo 5

VDS No. 6 located up-steam of Osoyoos Lake showing maintenance repairs, October 1991, in dyked channel area. [Dwg. 89-12-5]

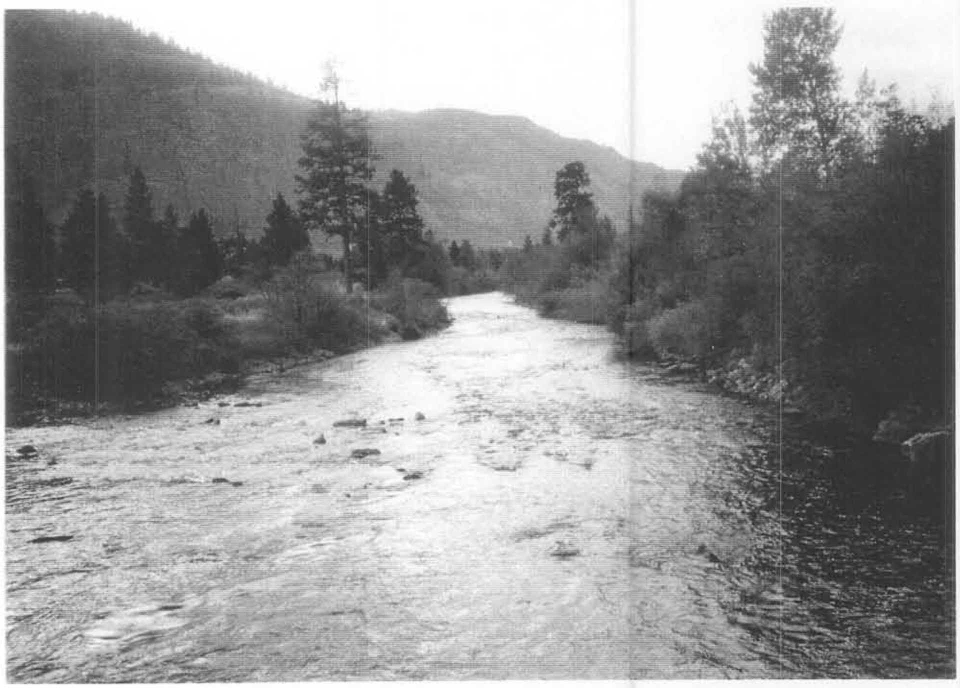


Photo 6

Okangan River immediately down-stream of the control dam at the Vaseux Lake outlet. [Dwg. 89-12-8]

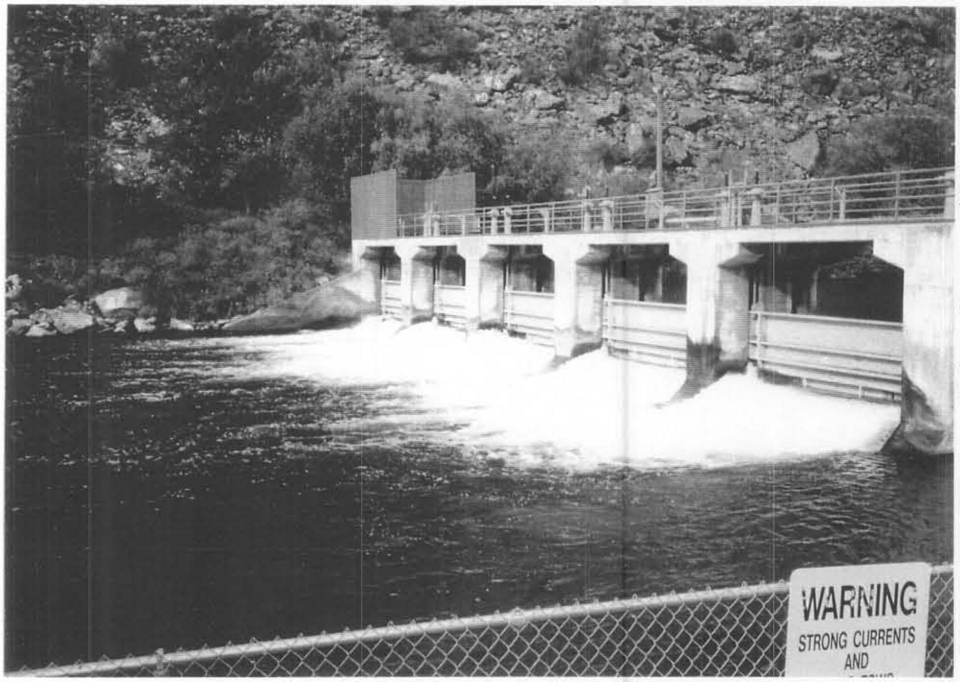


Photo 7

McIntyre (SOLID) Dam at outlet of Vaseux Lake.
[Dwg. 89-12-8]

Photo 8

Irrigation intake works at McIntyre Dam.
[Dwg. 89-12-8]

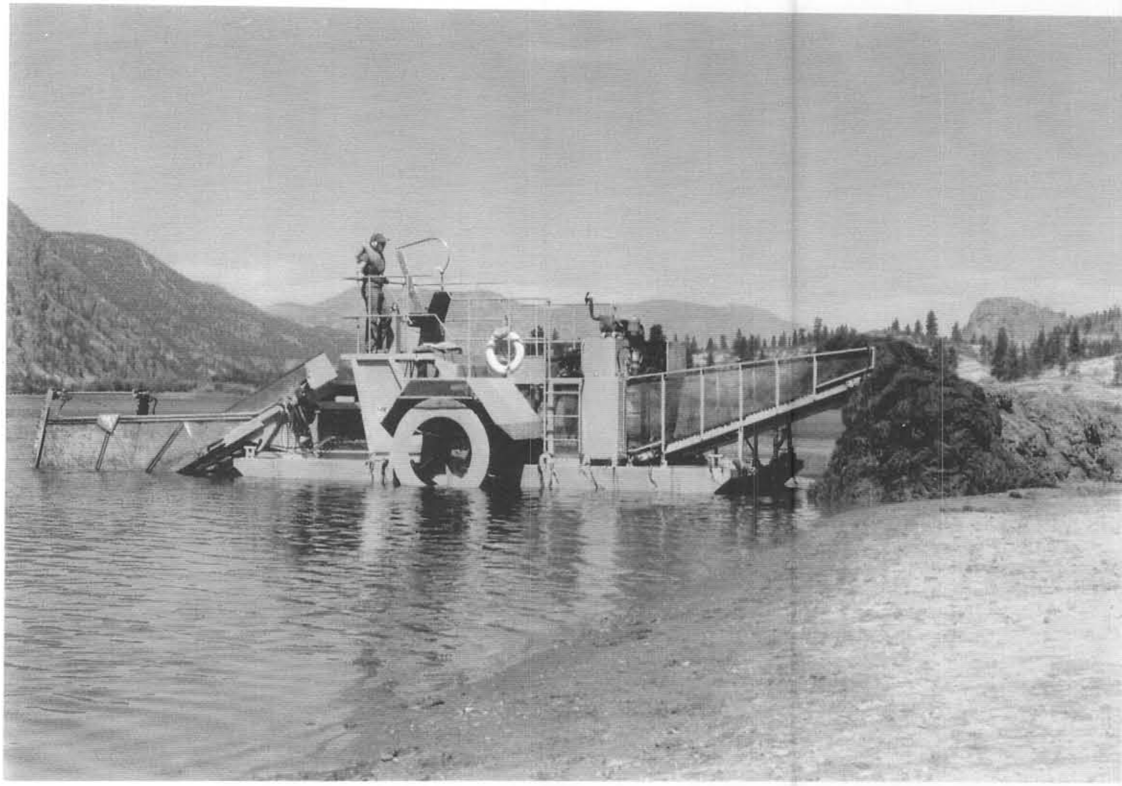


Photo 9

Aquamarine harvester discharging milfoil at temporary dumpsite, Vaseux Lake.

Photo 10

Typical aquatic weed harvesting of Eurasian milfoil in the Okanagan Valley.

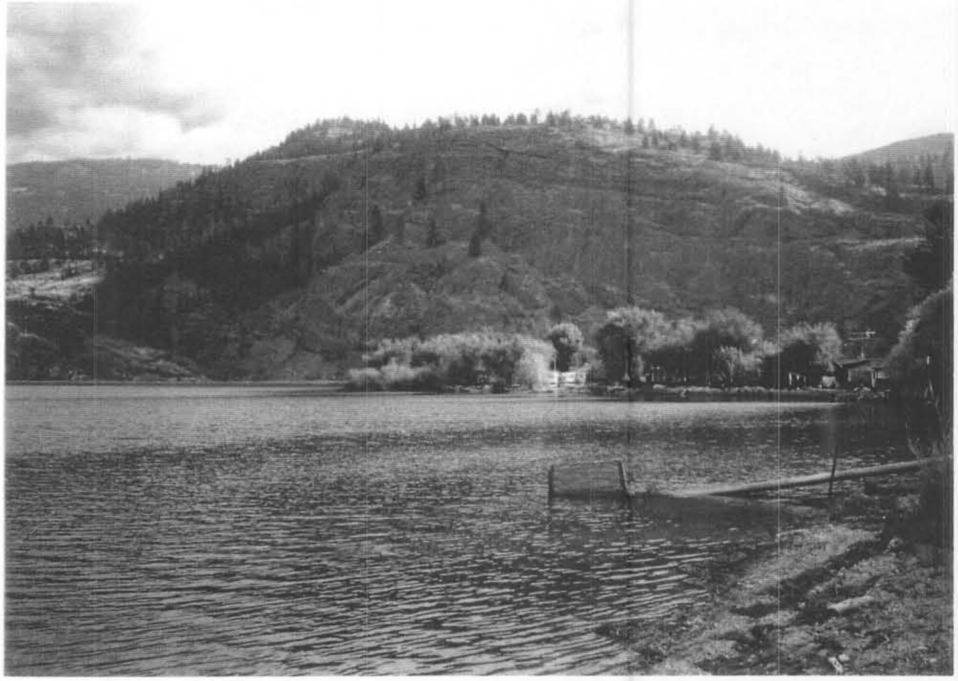


Photo 11

View of south end of Vaseux Lake showing existing homes in background.
[Dwg. 89-12-8]

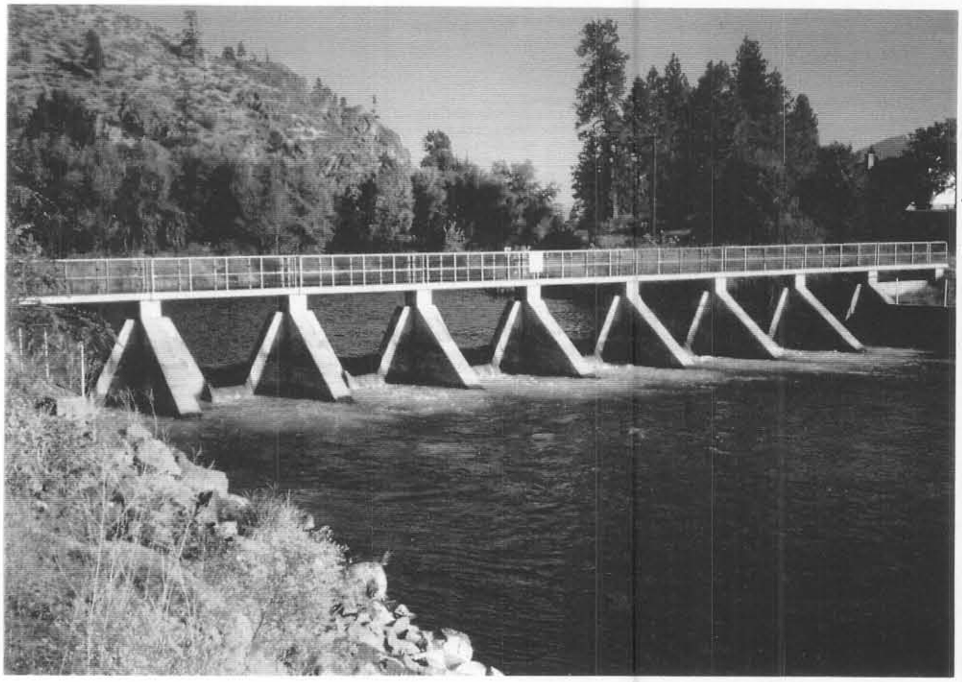


Photo 12

VDS No. 17 located between Vaseux Lake and Skaha Lake Dam.
[Dwg. 89-12-10]

Photo 13

Okanagan channel looking downstream from Skaha Lake Dam. [Dwg. 89-12-10]

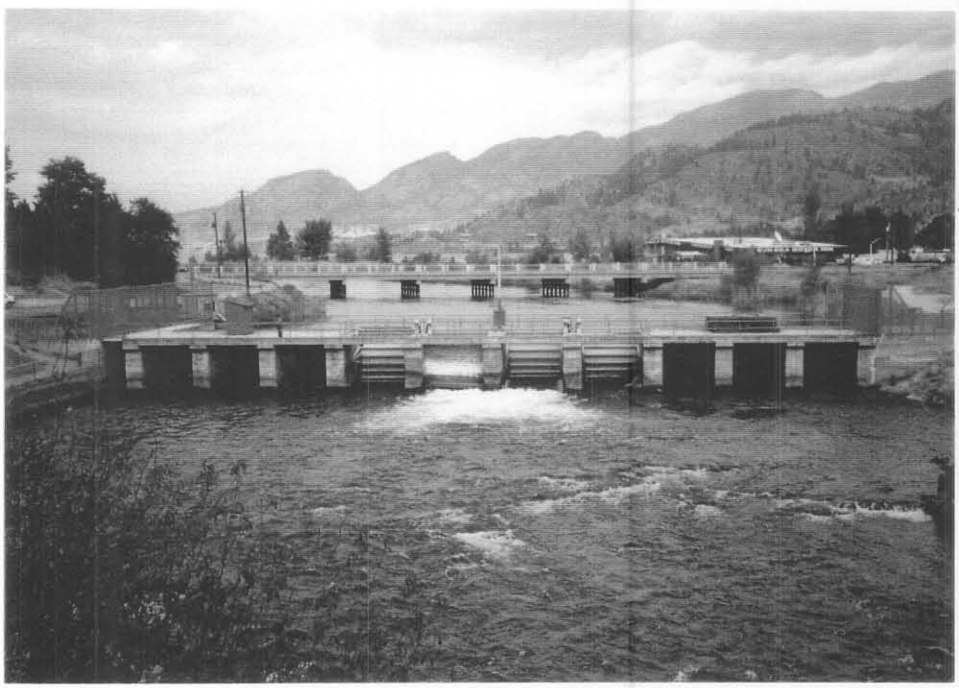


Photo 14

Okanagan channel looking upstream with Skaha Lake Dam in foreground, Skaha Lake in background. [Dwg. 89-12-10]

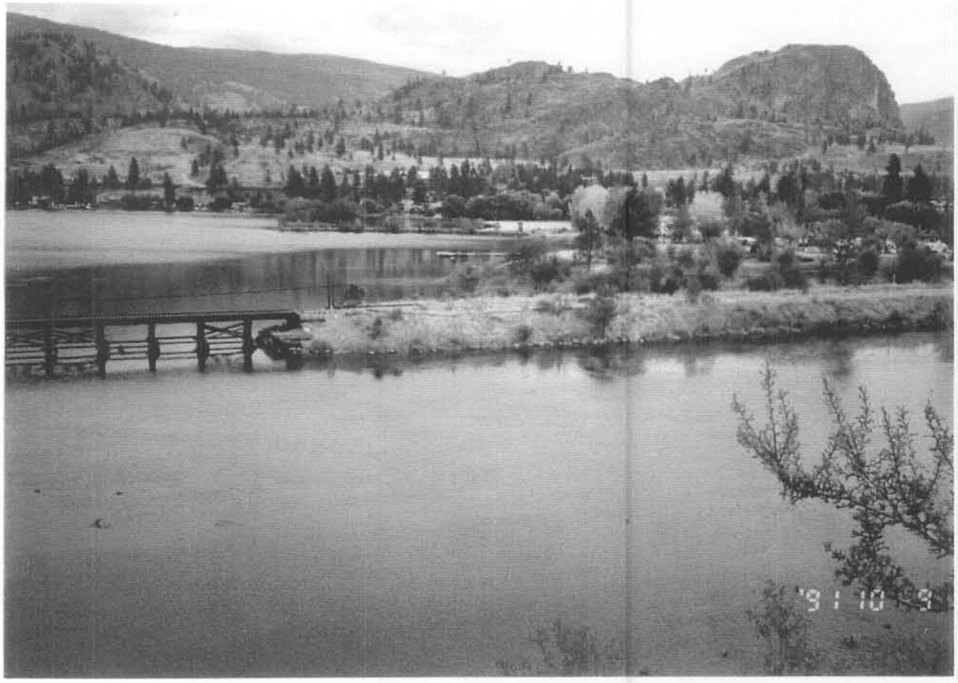


Photo 15

View of south end of Skaha Lake looking east towards homes at Okanagan Falls. (abandoned railway line in middle foreground). [Dwg. 89-12-10]

Photo 16

Okanagan channel located between Skaha Lake and Okanagan Lake looking downstream with Shingle Creek confluence area in right middle foreground. [Dwg. 89-12-14]

Photo 17

Dam at the outlet of Okanagan Lake.
[Dwg. 89-12-15]

Photo 18

View of the Okanagan Lake shoreline at Penticton just east of Okanagan Lake dam.
[Dwg. 89-12-15]

Photo 19

View of Penticton Creek concrete-lined channel in the City of Penticton.
[Dwg.89-12-15]

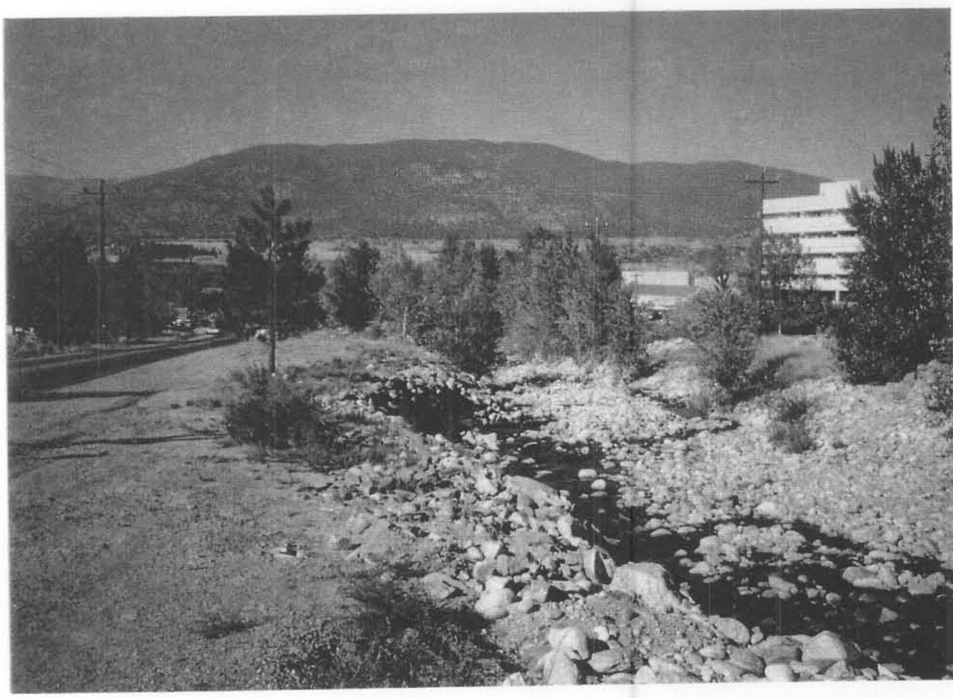


Photo 20

Ellis Creek in the City of Penticton.
[Dwg. 89-12-14]

Photo 21

Shingle Creek upstream of the Okanagan channel looking upsteam at debris stilling basin area.
[Dwg. 89-12-14]

Photo 22

Looking south across Vaseux Creek in the vicinity of irrigation canal crossing area showing berm (dykes) which parallel the creek.
[Dwg. 89-12-7]

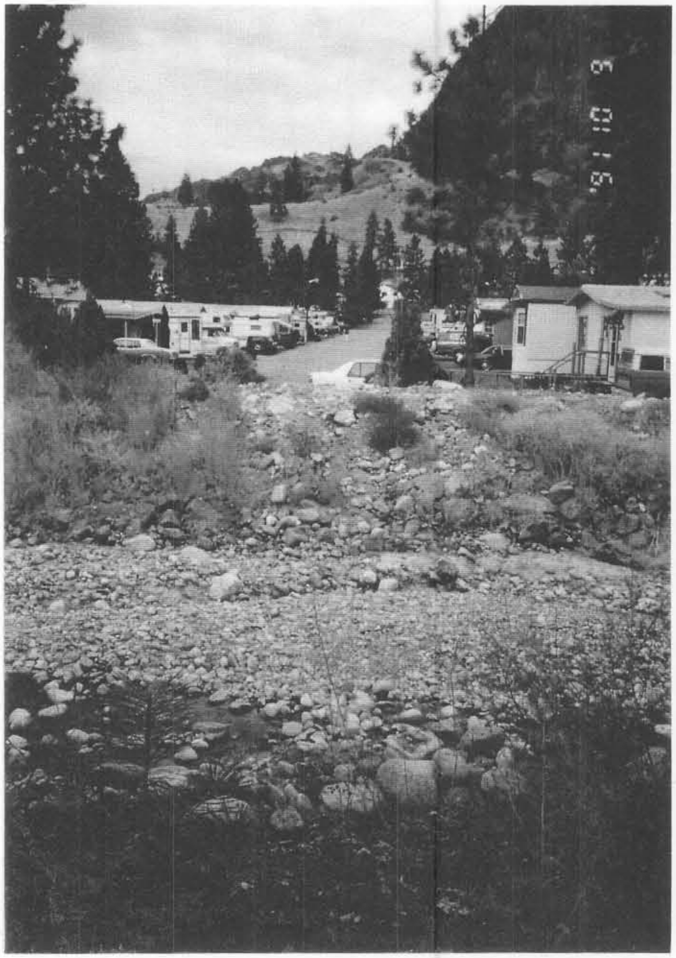


Photo 23

Shuttleworth Creek looking north towards berm protecting Mobile Home Park, opposite sawmill.
[Dwg. 89-12-10]

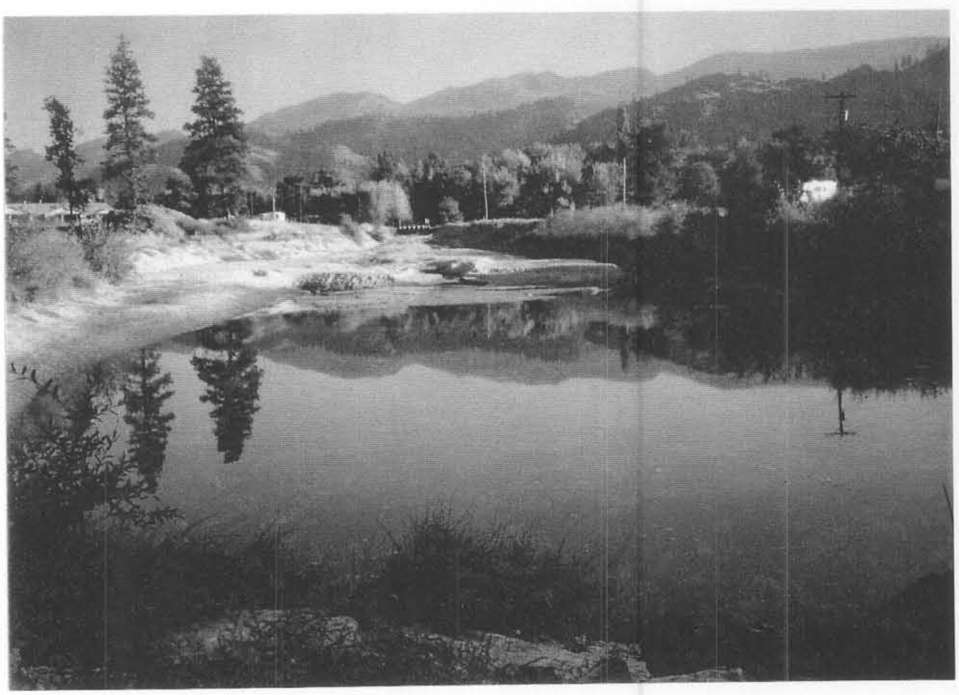


Photo 24

Debris stilling basin on Shuttleworth Creek upstream of Okanagan Channel.
[Dwg. 89-12-10]

APPENDIX 3

B.C. ENVIRONMENT

Water Management Division

HYDROLOGY SECTION

REPORT ON

FREQUENCY ANALYSES

OF FLOOD FLOWS AND LEVELS

for

OKANAGAN VALLEY

MAINSTEM SYSTEM

September, 1991

Files: S 5111
S 5211

R.Y. McNeil, P.Eng.,
Head, Hydrologic Modelling
Hydrology Section

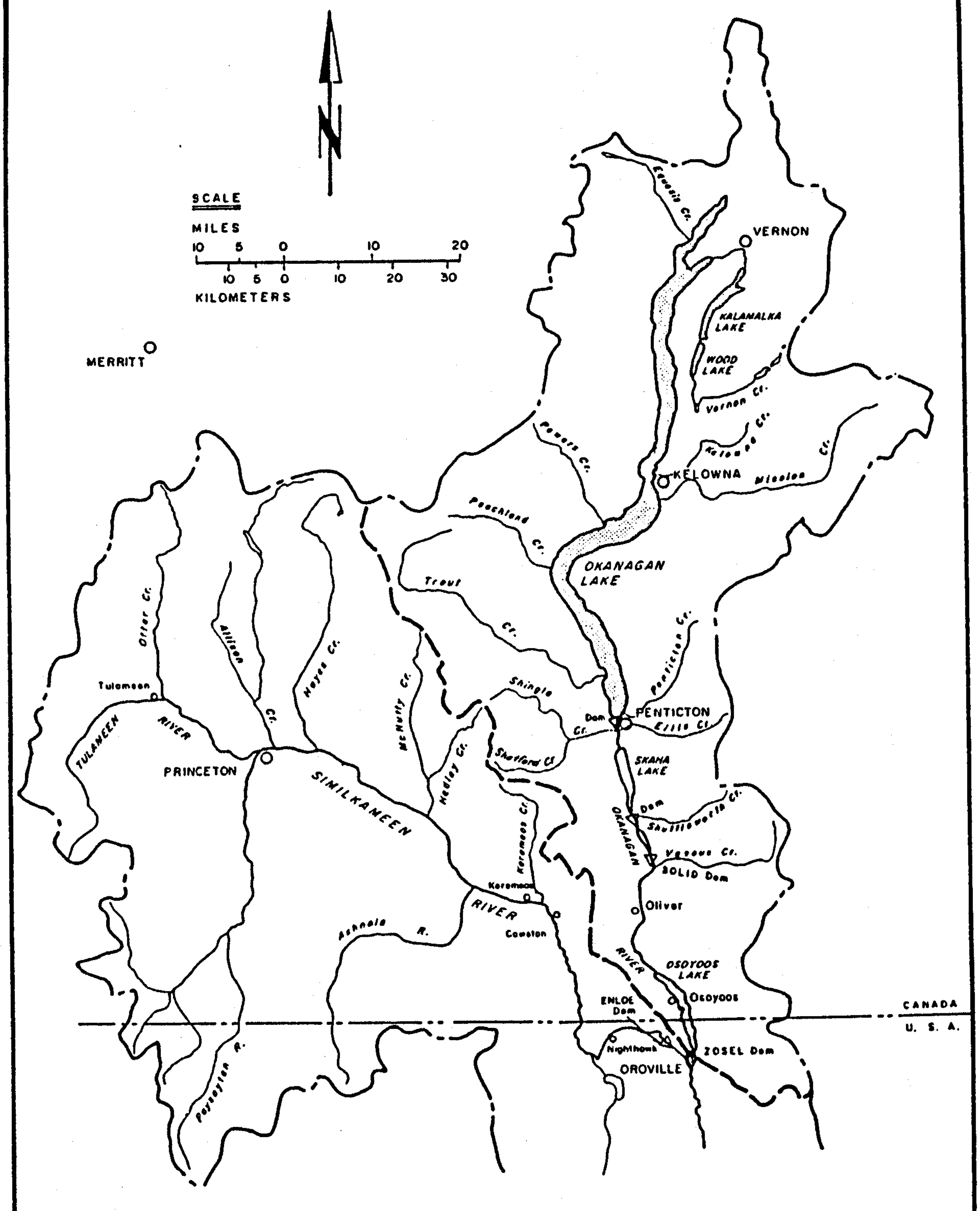
1. INTRODUCTION:

In a Memorandum dated November 6, 1990, Mr. R.W. Nichols asked that the Hydrology Section provide flow frequency analyses for various locations along the mainstem Okangagan Lake and River system. This analysis is required for floodplain mapping of the area under the Federal/Provincial Floodplain Mapping Program. This report summarizes the calculations and analyses made towards this end.

2. THE SYSTEM:

For the purpose of this report, the system is assumed to begin with Okanagan Lake which is controlled by Okanagan Lake Dam at Penticton. This is the major storage dam on the system, the reservoir having a surface area of 340 km^2 and a normal operating range of 1.2 m. Water released from this dam flows through a canal to Skaha Lake (area 19 km^2) which has a nominal operating range of 0.6 m, but which is normally kept close to mid range. Skaha Lake is controlled by a dam at Okanagan Falls and the water from here passes down a canal to Vaseux Lake and on to SOLID Dam about 2 km south of Vaseux. The operation of this dam (which exists to divert water into a major irrigation system) can have an effect on Vaseux Lake, particularly at low flows. However, at higher flows it is the capacity of the river channel to pass a given flow which determines the level of Vaseux Lake - this is often complicated by the growth of weeds in the channel. From SOLID dam, the river passes through a "natural" section of river channel before resuming its canalized passage into Osoyoos Lake. Osoyoos Lake level is largely controlled by Zosel Dam in Oroville, Washington State, but higher lake levels are always caused by high flows in the Similkameen River (which joins the Okanogan just south of Zosel Dam) blocking the outlet of the lake. Figure 1 shows the location of the system.

The present system including Okanagan Lake, Skaha Lake and SOLID dams were constructed in the early 1950s under a joint agreement between the federal and provincial governments. Following the Canada-British Columbia Okanagan Basin Study and Implementation Agreements in the 1970s, the responsibility for operation and maintenance of the system was given to British Columbia. Zosel Dam (originally built by a private mill-owner) was re-built in 1985 as a joint venture between Washington State and B.C. It is now owned and operated by the Washington State Department of Ecology under operating rules agreed with B.C. and approved by the International Joint Commission. The system in B.C. is owned by B.C. Environment and operated from their Penticton office. Guidance on operation is provided from the Ministry's Victoria office.



OKANAGAN - SIMILKAMEEN BASIN Figure I

3. BACKGROUND:

Although there are good long-term records at several of the gauges in the valley, this is not a simple analysis as there are virtually no natural streamflow records. As the valley is a water-short area, man has stored and diverted water in the valley from the time that the first settlers arrived. Thus, although there are 70 years of record at some gauges, there is no record of the natural flows in the main river system. This problem is addressed in the following report, but there does not seem to be any generally accepted method of dealing with the frequency analysis of non-natural flows. Obviously, to "naturalise" the flows prior to analysis is meaningless as there is no possibility of flows returning to natural and thus no purpose in calculating what the flows would have been had man not stored, diverted and canalised the water in the valley.

Because the majority of the peak lake levels are due to snowmelt floods, Okanagan Lake can be drawn down in anticipation of high volume runoff. If the lake goes above its "normal full pool" elevation, the operator has a choice between either restricting the outflow from the lake, thus reducing/eliminating flooding downstream but causing the lake to rise further, or releasing large volumes of water from the lake to the detriment of those downstream but minimising the damage around the lake. At some flow one would have to anticipate that there would be structural damage to, or failure of, the dykes containing the Okanagan River south of Okanagan Lake Dam if very high flows were released.

It is these unknowns of how the reservoir would be operated under extreme conditions and what the antecedent conditions would be that precludes one from estimating the 200-year level of Okanagan Lake by routing through "the" 200-year flood. It is quite possible that the 200-year lake level would be the result of heavy rain on a full reservoir rather than an extreme snowmelt event.

Extensive analyses of the availability of water in the Okanagan valley were made during the Federal-Provincial Okanagan Basin Study (1970-74) and there are several graphs of net freshet inflow frequencies for both floods and droughts in the Study report. However, there does not seem to have been much analysis of flow and level frequencies along the main stem of the valley other than for Okanagan and Osoyoos Lakes. It has not been possible to determine how the frequency analyses were done for these lakes at that time, only the estimated 200-year return period levels having been published.

4. AVAILABLE HYDROMETRIC DATA:

As stated above, there are reasonably long term records at many of the valley-bottom gauges in the Okanagan valley. These gauges are maintained by Environment Canada, Water Survey of Canada (WSC) who publish the data in a variety of forms. The following gauges were used in the analysis:

08NM071	Okanagan Lake @ Penticton	1921-74
08NM083	Okanagan Lake @ Kelowna	1944-90
08NM050	Okanagan River @ Penticton (Outflow from Okanagan Lake)	1922-90
08NM084	Skaha Lake @ Okanagan Falls	1943-90
08NM002	Okanagan River @ Okanagan Falls (Outflow from Skaha Lake)	1915-90
08NM085	Okanagan River near Oliver	1945-90
08NM073	Osoyoos Lake near Oroville (USA)	1930-90
08NM015	Vaseux Creek above Dutton Creek	1920-22 & 1959-82

The majority of the records available were taken as manual readings with the result that the period of record of instantaneous peak flows is generally much shorter than that for the daily peak flows. In fact, because the system is so controlled, it is possible to have some very sharp spikes in the hydrograph. E.g. during gate testing at a dam, a gate may be fully opened for half an hour, giving a high instantaneous peak flow for the day which has little relationship to the mean flow for the day. During normal operation, gate openings are changed relatively infrequently (typically weekly during the freshet and monthly otherwise) so that there is little difference between the peak daily and peak instantaneous flows. For these reasons, the analysis was restricted to peak annual daily flows and levels.

There are several smaller streams tributary to the main river between Penticton and the border but most of these have some storage/diversion and very short periods of record of flows. Also, because the area is very dry, flows tend generally to be very low for the great majority of the year. Apart from Vaseux Creek (which has no diversions of note), the principal tributaries are:

Shingle Creek - 308 km^2 - partial records for 10 years

Ellis Creek - 158 km^2 - partial records for 13 years

Shuttleworth Creek - 90 km^2 - partial records for 4 years at one gauge and 16 years at another

Park Rill - 160 km^2 - 20 years of seasonal data.

These records were not used in the analyses.

5. FREQUENCY ANALYSES AND OTHER RELEVANT DATA:

5.1 Okanagan Lake

The record of the lake gauge at Penticton starts in 1921 and ends in 1974, the years 1944 through 1974 being with a recording gauge and overlapping with the record of the lake gauge at Kelowna which started in 1944 and continues to the present day with the exception of 1949. Thus there is, potentially, a 70-year data set. Frequency analysis, however, assumes that the conditions have remained stable during the period from which the data are collected and this is generally assumed to be a valid assumption for natural streams. In the case of the majority of Okanagan valley gauges where the water flows are largely man-controlled, this assumption may not be correct. In the case of Okanagan Lake, little is known about the operation of the system prior to the building of the present dam. Even since the building of the dam there have been changes in the operation of the system as forecasting and reservoir operating techniques have been developed. It may therefore not be valid to use the full data set in the frequency analysis. The following table gives some of the 200-year return period stage (S_{200}) estimates and other data:

S_{200} from frequency analysis 1921-90 data	343.23 m
S_{200} from frequency analysis 1951-90 (modern operation) data	342.92 m
S_{200} from the Okanagan Basin Study Report	343.06 m
Flood Construction level (1974) - includes freeboard	343.66 m
Highest recorded lake level (1948)	343.13 m
Highest recent lake level (1990)	342.94 m

The frequency analysis of the 1951-90 data suggests that the 1990 peak level has a return period of greater than 200 years. This may not be unreasonable as there are estimates that the exceptionally heavy May-June rains which occurred when the reservoir was already close to full (as per the rule curve) may have had a return period of about 500 years! The difference of about 0.3 metres between the Q_{200} for the whole period of record and that for the "modern" operation, may well result from the increased discharge capacity of the dam and the ability to forecast inflows more accurately.

5.2 Okanagan River at Penticton

In spite of the fact that the flow at this gauge is totally controlled by the releases from Okanagan Lake Dam, the annual peak flows for the period 1922-90 were abstracted and run through a frequency analysis. As with Okanagan Lake, the "modern operation" data set (1951-90) was also abstracted and analyzed, giving the following data:

Q_{200} from frequency analysis, 1921-90 data .... 99 m^3/s

Q_{200} from frequency analysis, 1953-90 data .... 92 m^3/s

Maximum recorded flow (1978) .... 76.7 m^3/s

Design flow upstream of Shingle/Ellis Creeks .... 59.5 m^3/s

Design flow downstream of Shingle/Ellis Creeks .... 68.0 m^3/s

Drainage area .... 6090 km^2

Operating experience has shown that the channel capacity is considerably greater than the "design" capacity and there have been occasions on which design flows have been exceeded for considerable periods with little, if any, damage apparent.

A very simplistic analysis was made of the hydraulics of the control structure assuming that it was a broad-crested weir with all five gates (with a total width of 30.5 m) fully open. Using an (Imperial) Coefficient of Discharge (C_D) of 2.63, and a head of 11.1 ft (S_{200} of 1125.48 feet minus the sill elevation of 1114.39 ft) gives a theoretical discharge through the structure of 9,700 cfs or 275 m^3/s. This is almost five times the design flow but, due to the relatively flat slope of the channel downstream of the dam, such flows would almost certainly not be possible due to drowning out of the "weir" by backwater. However, it can be concluded that gate capacity will not be the limiting flow factor at the outlet of Okanagan Lake. This is borne out by operating experience.

5.3 Skaha Lake

The "official" operating limits for Skaha Lake are the relatively narrow band from 337.6 to 338.2 metres. Because Skaha Lake's surface area is only about 6% of Okanagan Lake's, it is not generally used to store water and is normally kept close to the middle of its range. Frequency analyses of the "modern operation" data were conducted with the results as follows:

Q_{200} from frequency analysis, 1953-90 data .... 338.34 m

Flood Construction Level, including freeboard (1974) .... 339.24 m

Highest recorded level (1948) .... 338.56 m

Highest recorded recent level (1972) .... 338.18 m

Normal upper operating limit .... 338.21 m

During the high flows in the summer of 1990, it was noted that the capacity of Skaha Lake Dam had been reached in that all four gates were clear of the water and, under relatively steady inflow conditions, the lake was essentially stable. This allowed a calculation of the C_D of the structure, hence giving the head necessary to pass a given flow. With a sill elevation of 335.769 m, free flow was observed with a lake level of 337.860 m and a recorded flow at Okanagan Falls of 62.8 m^3/s. The dam has 4 radial arm gates, each 3.96 m wide. This gives a C_D of 1.31. Using $Q = C_D * L * H^{1.5}$, where L is the total gate width allows one to calculate the theoretical lake level for any given flow, and vice-versa. It should be noted that, in an emergency, it would be possible to remove stoplogs from the six bays in the dam which are ungated, thus allowing the dam capacity to be increased above the values given by the above equation.

5.4 Okanagan River at Okanagan Falls

This gauge is immediately downstream of the Skaha Lake dam, so flows are entirely man controlled except when, at very high flows, the dam capacity becomes the limiting factor. The following data are relevant:

Q_{200} from frequency analysis, 1953-90 data . . . . 98 m^3/s

Highest recorded flow (1990) . . . . 76.7 m^3/s

Drainage area . . . . 6860 km^2

5.5 Vaseux Lake

Vaseux Lake is a widening of Okanagan River upstream of Oliver. It has only very recently (spring 1991) had an official gauge installed, so there are no historic levels to analyze. The outlet of the lake is uncontrolled, but there is a dam (McIntyre or SOLID) about a mile downstream that may affect lake levels at low flows. Vaseux Lake and the downstream channel are quite shallow and have become clogged with *Eurasian milfoil* in the past few years. These weeds have to be cut regularly to maintain sufficient channel capacity to allow passage of the water without Vaseux Lake reaching excessive levels. Obviously, the head required on Vaseux Lake to pass a given flow will vary according to how badly the river channel is clogged by weeds. This makes it very difficult to assess what lake level would correspond to the Q_{200} proposed for the outlet from the lake. It is suggested that HEC-2 analyses of flows through this reach be conducted before a 200-year stage is finalized for Vaseux Lake. It is possible that such an analysis might show if there were an economic way to increase the channel capacity and thereby reduce the frequency of flooding around the lake.

5.6 Vaseux Creek above Dutton Creek

Although Vaseux Creek is not part of the study, it was analyzed because it is the only sizable tributary to the main river which has a reasonable period of record and has natural flow. The 27-year record of annual maximum daily discharge was analyzed using FREQAN with the following result:

Q_{200} from frequency analysis, 1920-22 & 1959-82 data .... 39 m^3/s

Maximum recorded flow .... 32.8 m^3/s

Drainage area .... 255 km^2

5.7 Okanagan River near Oliver

There are 42 years of data for this station and the frequency analysis of the daily peak annual data appeared to find a good fit to the data. A second run using only "modern operation" data was also conducted. The results are as follows:

Q_{200} from frequency analysis, 1945-90 data .... 125 m^3/s

Q_{200} from frequency analysis, 1953-90 data .... 133 m^3/s

Maximum recorded flow .... 104 m^3/s

Drainage area .... 7590 km^2

5.8 Osoyoos Lake near Oroville

During the summer, Osoyoos Lake normally operates in the range of 277.60-277.75 m (Canadian datum). During very high flows in the Okanagan River, this may rise as high as 278.6 m to provide sufficient head to pass flows of over 110 m^3/s through the system. However, the highest Osoyoos lake levels are due to an entirely different mechanism - the backwater from flooding in the Similkameen river which joins the Okanogan about a mile south of the control structure at the outlet of Osoyoos Lake (Zosel Dam). Flows of over about 280 m^3/s in the Similkameen cause a restriction in the outflow from Zosel Dam. Although there are two mechanisms, the combined data set appears to be relatively continuous and it would be almost impossible to separate the two data sets since they tend to occur at the same time of year and are not totally independent. A study on a coastal stream which had both snowmelt and fall rain events concluded that combining the two data sets into a single frequency analysis gave very similar results to a complicated technique for combining two analyses.[1] Also in *Hydrology of Floods in Canada*[2], the following is stated:

> "In theory ..an argument exists for treating most Canadian series as composed of two or more samples from different populations. Practically, however, such treatment considerably complicates the preparation of a frequency analysis, and there is little reason to do so unless treatment as a single population produces a

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[1]Memo to J.D.C. Fuller from R. McNeil, file 0323545, 1985-02-29 (*sic*)

[2]Watt, W. E., ed. *Hydrology of Floods in Canada*, National Research Council, p 56.

peculiar shape of frequency curve or there are reasons for determining separate design floods for the two types."

Accordingly, a frequency analysis of the complete data set (1930-90) was made - there being little point in extracting the "modern operation" series because the dominant effect at high levels is due to natural rather than man-made operation. The following data are relevant:

S_{200} from frequency analysis, 1930-90 data, (Canadian datum[3]) . 279.87 m

Highest lake level reported (1894) .... 279.95 m

Highest lake level recorded (1934) .... 279.49 m

Highest "recent" lake level (1972) .... 279.44 m

Flood construction level (inc. freeboard) (1974) .... 280.72 m

5.9 Local Inflow Penticton-Oliver

There are 45 common years of data for the gauges at Penticton (08NM050) and Oliver (08NM085). The difference between the two gauges should give a reasonably good estimate of the inflow from the tributaries along the river, assuming that there is no significant change in storage in Skaha/Vaseux Lakes. To create a data set of the annual maximum tributary inflow it was assumed that there was a 1-day lag between Penticton and Oliver. The April through June data were then scanned to find the greatest difference between the flow at Oliver and the previous day's flow at Penticton. This difference was then assumed to be the maximum annual daily inflow between Penticton and Oliver. As these tributary inflows are mostly natural (during peak runoff), there is no advantage in abstracting a "modern operation" data set. The following are of interest:

Q_{200} from frequency analysis, 1945-90 data .... 59 m^3/s

Maximum "observed" inflow (1990) .... 48.2 m^3/s

Increase in drainage area between Penticton & Oliver ...... 1500 km^2

6.0 METHODOLOGY USED TO ESTIMATE UNGAUGED FLOWS:

Although the main body of water in the Okanagan is man controlled in Okanagan Lake as are the releases therefrom, the tributary streams joining the river are, to all intents and purposes, not controlled. These creeks downstream of Okanagan Lake are relatively short, in the driest part of the basin and, during a normal snowmelt peak, they would normally peak well before Okanagan Lake filled. The channel design capacity is for an

[3] Subtract 0.08 m from U.S. datum to convert to Canadian

increase from 60 to 96 m^3/s between Okanagan and Osoyoos Lakes, certainly considerably less than the increase that would occur if the 200-year event were to occur over all the south half of the valley simultaneously. The challenge, therefore, is to determine a realistic figure for the tributary inflow that can logically be added to the release from Okanagan Lake.

Water Survey of Canada in their publication entitled *Magnitude of Floods in B.C.* publish a graph of extreme recorded floods in B.C.. This indicates that, for any hydrologically homogenous region there is a relationship between area and runoff of the form:

$$Q = k \bullet A^{0.76}$$

where Q is the flow in cubic metres/second
k is a constant for that hydrologic region and
A is the drainage basin area in square kilometres.

If this formula is applied to the suggested Q_{200} for Vaseux Creek (drainage area 255 km^2), a value of k of 0.578 is indicated. This implies that the 1500 km^2 drainage area between Penticton and Oliver would generate an additional flow of 150 m^3/s over and above the release from Okanagan Lake Dam. This seems to be much too high.

If the formula is applied to the Q_{200} for the drainage basin between Penticton and Oliver as described in Section 5.9, above, a value of k of .228 is indicated and this seems much more reasonable. The following recommended 200-year return period flows are the greater of the suggested Q_{200} release from Penticton or the sum of the design flow release from Penticton (60 m^3/s) plus the flow indicated for the increase in drainage area using the above formula with k=0.228.

7.0 SELECTION OF 200-YEAR LEVELS AND FLOWS.

7.1 Okanagan Lake

The peak level attained by Okanagan Lake depends on human input through forecasts of inflow and the decisions made regarding drawdown of the lake prior to the freshet. Unexpected events (such as the unprecedented rains in May-June 1990) can result in the forecasts being very wrong. The frequency analysis of the peak annual levels of Okanagan Lake for the "modern operation" suggests an S_{200} for Okanagan Lake which is slightly below that which occurred last year. While this is possible, there seems no good reason to change the Flood Construction Level of 343.66 m which has been in effect since 1974. This implies that the S_{200} for Okanagan Lake be 343.05 m.

7.2 Releases from Okanagan Lake

Because the flows released from Okanagan Lake Dam can, to a very great extent, be controlled, it is likely that the 200-year event downstream of the dam will be the result of a human decision rather than a direct natural event. If maximum releases at Penticton were required when the downstream tributary streams were relatively low, the limitation would presumably be the channel capacity in the reach down to the point where Shingle and Ellis Creeks join the Okanagan River. It is therefore suggested that the Q_{200} resulting from the analysis of the modern operation data - 92 m^3/s - be adopted. However, it seems reasonable to assume that, were the tributary streams in full spate, releases at Okanagan Lake Dam would be cut back, if necessary, to the design flow (60 m^3/s).

7.3 Skaha Lake

As the gate capacity of Skaha Lake Dam appears to be the controlling factor (assuming stoplogs are not removed), the S_{200} for Skaha Lake is assumed to be the level corresponding to the Q_{200} flow with all gates open. Using Q_{200} of 96 m^3/s as discussed in the next section results in a Skaha Lake S_{200} of 338.55 m. This is not much greater than the S_{200} suggested by the frequency analysis of the recorded "recent" peak levels and allows a freeboard of 0.69m to the Flood Construction Level that has been in existence for many years.

7.4 Outflow from Skaha Lake

The increase in drainage area between Okanagan and Skaha Lake dams is 770 km^2. This implies an increase in flows of 36 m^3/s using the methodology suggested in Section 6. This, added to the design release of 60 m^3/s is greater than the 92 m^3/s recommended as the Q_{200} for releases from Penticton. Thus, 96 m^3/s would be the recommended figure.

7.5 Okanagan River near Oliver

The increase in drainage area between Okanagan Lake Dam and the gauge near Oliver is 1500 km^2 and the increase in the 200-year return period has been calculated as 59 m^3/s. If this is added to the design release from Okanagan Lake Dam, the Q_{200} at this gauge becomes 119 m^3/s or about 14% higher than has been recorded to date. This seems reasonable and should be well within the capacity of the channel.

7.6 Osoyoos Lake

As the peak levels of Osoyoos Lake in extreme years are largely independent of the flows released from Penticton, there does not seem to be any reason to change the S_{200} suggested by the frequency analysis of 279.87m. This is 0.85m below the Flood Construction Level which has been in effect in the area since 1974.

8 RECOMMENDATIONS:

The recommended flows have been given in the preceding section and are summarized in the table below. Intermediate points can be calculated using the formula given. This implies that the Operating Rules for Okanagan Lake Dam will have to be amended so that the operator is aware that there could be circumstances in which he was obliged to cut back on releases at Penticton to ensure that 200-year return period flows in the following table were not exceeded downstream

The Q_{20} and S_{20} figures have been calculated in a similar manner to the 200-year figures. For the reasons described above, no estimates of instantaneous flows are given.

Location	Drainage Area km²		Return Period	
	Total	Local	20-yr	200-yr
Okanagan Lake	6090		342.90	343.05 m
Okanagan River at Penticton	6090		70	92 m^3/s
OK River d/s Ellis & Shingle Cks	6556	466	78	92 m^3/s
Skaha Lake	6860		338.23	338.55 m
OK River at OK Falls	6860	304	87	96 m^3/s
OK River d/s Shuttleworth Ck	6950	90	89	99 m^3/s
Vaseux Lake	N/A	N/A	N/A	N/A
OK River d/s Vaseux Ck	7390	440	100	113 m^3/s
OK River at Oliver	7590	200	105	119 m^3/s
Osoyoos Lake	8100	510	279.26	279.87 m

Table 1 : Recommended Lake Levels and Flows

APPENDIX 4

FLOODPLAIN MAPPING
OKANAGAN RIVER

DRAWING 89-12, SHEETS 1 TO 15*

* provided under separate cover