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Economic Analysis of Replacement of Zosel Dam

Prepared by
R. McNeill

June 1983

Inland Waters Directorate
Pacific and Yukon Region
Vancouver, B.C.

ENVIRONMENT CANADA

ENVIRONMENTAL CONSERVATION SERVICE

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SUMMARY

A. Objective

The objective of this study is to determine the economic benefits to Canada of replacing Zosel Dam. The major benefit to Canada and British Columbia of replacing Zosel Dam is increased security against dam failure which would result in a drop in summer lake levels in Osoyoos Lake.

The study does not examine the question of responsibility for losses that would occur because of the lower lake levels nor does it examine the benefits of a new structure to the United States. The analysis of the benefits is kept separate from the question of liability of damages in the event of the present dam failing.

B. Proposed Replacement Structure

The proposed structure is in the concept phase and the final design and cost estimates are not available. It will be located on the Okanogan River near the present Zosel Dam.

C. Basic Assumptions

If Zosel Dam fails, lake levels will drop to 908 feet north of Haynes Point and 906 feet south of Haynes Point. This compares to the usual summer elevation of approximately 911 feet.

Economic life of a replacement dam is 40 years.
Discount rate is 10%.
Demands for water based recreation are increasing at an uncompounded rate of 1.78% per year.

D. Results of Study

The benefits to Canada or British Columbia of a replacement structure vary according to the risk of failure of Zosel Dam. Therefore, the benefits were calculated for a number of risk scenarios, where each scenario showed probabilities of dam failure over the next 10 years. Table 1 shows the benefits for each risk scenario.

TABLE 1

Benefits for Different Risk Scenarios

Risk Scenarios	Probability of Failure Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Benefits
Scenario A	1.0	0	0	0	0	0	0	0	0	0	$2,029,000
Scenario B	.9	.1	0	0	0	0	0	0	0	0	2,012,000
Scenario C	.8	.1	.1	0	0	0	0	0	0	0	1,980,000
Scenario D	.7	.1	.1	.1	0	0	0	0	0	0	1,933,000
Scenario E	.6	.1	.1	.1	.1	0	0	0	0	0	1,874,000
Scenario F	.5	.1	.1	.1	.1	.1	0	0	0	0	1,802,000
Scenario G	.4	.1	.1	.1	.1	.1	.1	0	0	0	1,720,000
Scenario H	.3	.1	.1	.1	.1	.1	.1	.1	0	0	1,627,000
Scenario I	.2	.1	.1	.1	.1	.1	.1	.1	.1	0	1,086,000
Scenario J	.1	.1	.1	.1	.1	.1	.1	.1	.1	.1	543,000

E. Conclusions

At high risks of failure, the benefits to Canada or British Columbia are in the order of $2 million. However, the benefits are much lower at low levels of risk. This points out the need to arrive at an acceptable estimate of the risks of Zosel Dam failing before any Canadian funds are committed towards its replacement.

The benefits were determined using a data base that was weak in some areas. Further field surveys and consultation with the Province of British Columbia and State of Washington would likely result in a better data base and more accurate analysis of the benefits.

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A. Introduction

Zosel Dam is located on the Okanogan River in the State of Washington (Figure 1). Despite some seepage problems, the structure is used to maintain the level of Osoyoos Lake during the summer, fall and winter. However, it is now in a deteriorated condition and is no longer able to maintain lake levels without risk of failure.

Both British Columbia and the State of Washington are concerned with the possibility of the dam failing. At the request of the State of Washington, the United States Army Corps of Engineers examined the structure in 1978 and concluded that it was overstressed at normal summer lake elevations. Repairs to ensure the integrity of the dam were done in 1978 but were regarded as temporary. At the International Joint Commission (IJC) public hearing in December 1981, several groups expressed concern with the unsound condition of the dam, and the Osoyoos Lake Board of Control recommended that it be replaced within three years.

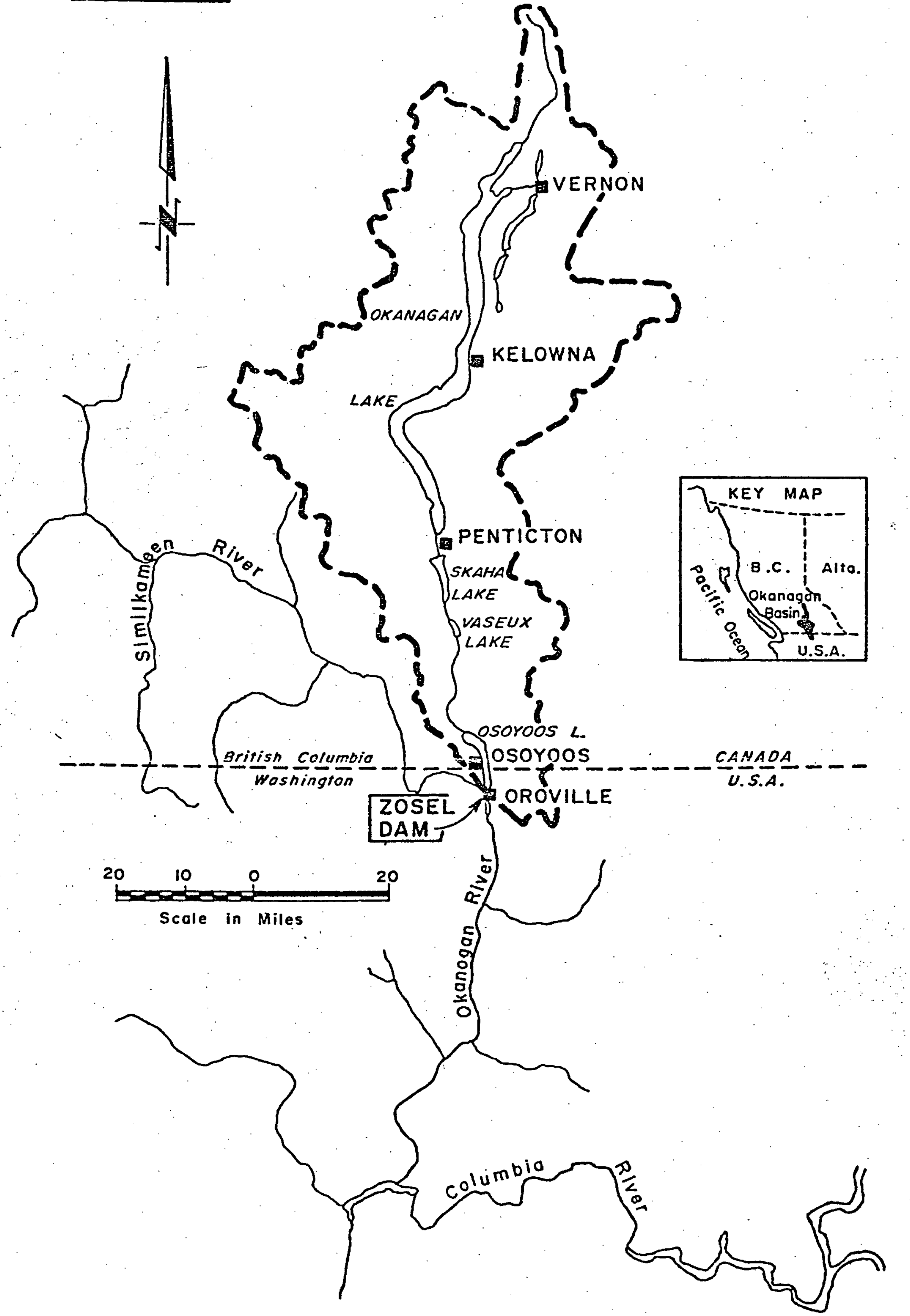
If the dam failed and emergency measures were not taken, summer lake levels on Osoyoos Lake would drop by at least three feet. At these lake levels, most domestic and agricultural water intakes would be inoperable. Boat launches would, for the most part, be unusable and significant boating activity on the lake would be lost. Substantial areas of lake bottom would be exposed, reducing the user-value of these areas for swimmers and boaters.

B. Proposed Solution to Problem

In 1981 the State of Washington applied to the IJC for permission to replace Zosel Dam with a new structure. The IJC granted an order of approval on December 9, 1982 to replace the present structure, with the approval being contingent on a number of conditions specified in the order. The State of Washington has accepted these conditions and is ready to proceed with replacement of Zosel Dam.

The proposed new structure would perform the same basic function as the old structure and would provide a more accurate control of lake levels in some years because of reduced seepage. The new structure would also be able to maintain an extra foot of storage on Osoyoos Lake which could be utilized in drought years.

FIGURE I OKANAGAN RIVER DRAINAGE BASIN



A current cost estimate of the new structure is not available, although previous estimates by the United States Army Corps of Engineers (1979) were in the order of $4 million (U.S. Dollars). No agreement on funding and no formal requests to Canada for sharing in the costs have been made. Officials from British Columbia and Washington have had discussions on cost-sharing, and the British Columbia Deputy Minister of Environment has requested discussions on cost-sharing with the federal Deputy Minister of Environment. Furthermore, provincial officials have expressed interest in federal assistance in determining the benefits to Canada of a new structure. Because formal negotiations on funding for the new structure may involve the relative distribution of benefits between the parties, an analysis of benefits to Canada was undertaken.

C. Objective

The objective of this study is to determine the economic benefits to Canada or British Columbia of replacing Zosel Dam. Other criteria related to funding of a new structure, such as the level of benefits to the United States and the responsibility for losses resulting from failure of Zosel Dam, are not examined in this study.

D. Method of Analysis

Two basic alternatives to immediate replacement of Zosel Dam are considered:

(1) Carry out mitigative measures to reduce the losses that would occur from a failure of the present Zosel Dam.

(2) Replace Zosel Dam at a later date.

With each of these alternatives some costs and damages could occur which would be prevented by immediate replacement of Zosel Dam. The value of these costs and damages are savings attributable to a new dam and represent upper limits to the benefits of replacing the dam at this time. An analysis of these alternatives is done in the next sections.

1. Alternative One: Mitigative Measures to Reduce Losses

The question of when to carry out these mitigating measures was first addressed. Two options were considered:

(1) wait until the present structure fails and then modify intakes, boat launches and docks so that they are usable at the lower lake elevations; and,

(2) undertake modifications to intakes, boat launches and docks immediately or as soon as possible in order to minimize losses in the event of a dam failure.

Based on a preliminary analysis (section E.2) it was determined that the best option was (1) above, which was to modify intakes, launches and docks when the present Zosel Dam fails. It was found that this alternative could be carried out at a relatively low cost and would prevent a major portion of the agricultural and recreational losses that would otherwise occur at the lower lake levels. Some immediate losses to agriculture and recreation would probably still occur since modifications to intakes, launches and docks could not be made immediately in the event of a dam failure. There would also be some continuing annual losses to boaters and beach-users because of substantial exposure of lake-bottom in some areas. Table 2 summarizes the costs and losses associated with this option if Zosel Dam were to fail.

TABLE 2

Losses Associated with Failure of Zosel Dam

Loss	Occurrence
Cost of replacing intakes, launches and docks	Single capital cost occurring in year of dam failure
Short term losses to agriculture and recreation	One-time loss occurring in year of dam failure
Long term losses to Recreation due to lake-bottom exposure	Continuing annual losses commencing in the year of dam failure

We cannot predict exactly when the present Zosel Dam will fail, although evidence suggests that the risk of failure is significant. If the probability of failure can be estimated over a number of years, we can express the losses described in Table 2 on an annual flow basis. This is shown in equation (1).

(1) $C_i = p_i\,(KC + STL) + P_i\,(RL)$

where: C_i = cost in year i

KC = capital costs of modifications to intakes, boat launches and docks

STL = short term losses to agriculture and recreation

RL = continuing annual recreational losses due to exposure of lake-bottom

p_i = probability that the present Zosel Dam will fail in year i

P_i = probability that the present Zosel Dam will fail or has already failed by year i.

If the present Zosel Dam is replaced by a new dam, then the costs in equation (1) will not be incurred. The annual savings of a new dam are thus equal to the annual costs shown in equation (1).

The benefits to Canada will be less than or equal to the present value of these savings. This condition can be expressed as:

(2) $PVB \leq \sum_{i=1}^{n} C_i/(1+r)^i$

where: PVB = Present value of the benefits

n = life of replacement dam

r = interest rate.

Since a year by year quantified estimate of the risk of Zosel Dam failing was not available, the benefits were calculated over a range of probabilities of dam failure.

2. Alternative Two: Replace the Dam at a Later Date

At low levels of risk of failure, it may be more economic to delay construction of the replacement dam in order to realize a saving on the interest costs of the capital investment. However, a risk is taken in that the present dam could fail with little warning resulting in agricultural and recreational losses, that would occur before a new dam could be constructed. It is assumed that the full recreational season would pass before a new dam would be constructed and lake levels restored. If the saving from waiting another year is greater than the costs of waiting, then construction of a new dam should be delayed. In other words the replacement structure should be delayed if equation (3) holds.

(3) $$r \times KN = p_i \ (AL + BTL + BCL + CI)$$

where:

r = interest rate

KN = cost to Canada or British Columbia of new dam

AL = agricultural losses which would occur before modifications could be made to intakes to accommodate lower lake levels

BTL = losses to recreational boaters while boat launches are unusable

BCL = losses to beach users due to lower lake levels

CI = costs of modifying intakes to operate at lower lake levels

p_i = probability of the present dam failing in year i.

The losses represented in equation (3) are similar to but not the same as the short term losses (STL) shown in equation (1). The difference lies in losses to recreational boaters and the costs of modifying boat launches. In equation (3) which represents a comparison of costs over a single year, it was found to be less costly to lose a full year of recreational boating than to replace the boat launches and docks. The BTL in equation (3) thus represents the value of a full season of boating, while the STL term in equation (1) includes only a portion of the value of a full boating season plus the costs of modifying launches and docks. Losses to beach users are equivalent in both equations although in equation (2) they are grouped with annual boating losses into the RL term.

Equation (3) can be rearranged to give the maximum cost at which immediate replacement of the structure would be preferable to waiting another year as displayed by equation (4). This equation represents the criterion of optimal timing of the replacement structure.

$$(4) \quad KN = p_i \ (AL + BTL + BCL + CI)/r.$$

If the replacement dam were to be built immediately, equation (4) represents a limit on the economic rent to Canada or British Columbia . Thus the equation represents a limit to the benefits of immediate replacement of Zosel Dam. Since we do not have a quantified estimate of the present structure failing, equation (4) is solved over a range of risk estimates.

3. Summary

In summary, there are two separate factors which limit the benefits of the replacement structure to Canada or British Columbia.

(1) The benefits are less than or equal to the present value of the savings of replacing the dam over the best non-replacement alternative. This limit is expressed in equation (2).

(2) The benefits are less than or equal to a certain level which satisfies the criterion for optimal timing of the replacement structure. This limit is expressed in equation (4).

The two limits will not necessarily be equal, but both will vary according to the risk of failure of the present Zosel Dam. In order to define the benefits to Canada or British Columbia we can estimate the two limits at each level of risk and choose whichever is less.

E. Analysis of Mitigative Measures to Reduce Losses

1. General Assumptions

a) If Zosel Dam fails, lake levels will drop to 908 feet north of Haynes Point and 906 feet south of Haynes Point (see Figure 2). The two lake levels would occur because of a sand bar running across the lake from Haynes Point. This compares to the usual summer elevation of about 911 feet.

b) The demand for boating and swimming on Osoyoos lake will grow at an uncompounded rate of 1.78% annually from current levels as projected by Phipps and James (1980).

c) Interest rate is 10%.

d) Base year is 1982.

e) Economic life of the replacement structure is 40 years.

2. Costs of Modifying Intakes, Boat Launches and Docks

A preliminary analysis showed that modification of intakes, boat launches and docks was the best alternative to construction of a replacement dam. The intakes could be modified to operate at the lower lake levels at a cost of $39,000 (including engineering and administration). If Zosel Dam were to fail,

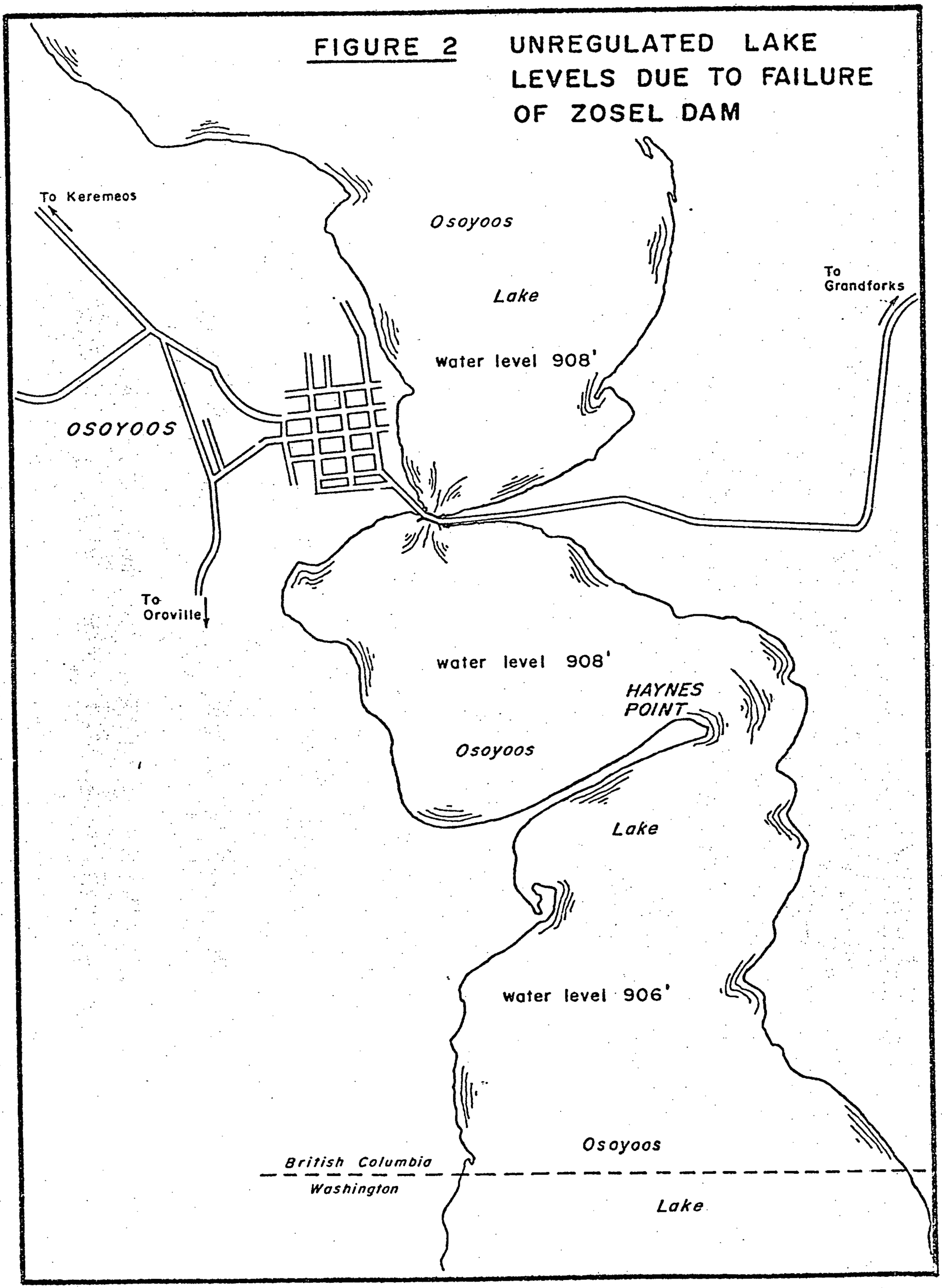


FIGURE 2 UNREGULATED LAKE LEVELS DUE TO FAILURE OF ZOSEL DAM
To Keremeos
Osoyoos
Lake
To Grandforks
water level 908'
OSOYOOS
To Oroville
water level 908'
HAYNES POINT
Osoyoos
Lake
water level 906'
Osoyoos
British Columbia
Washington
Lake

these modifications would allow irrigation to continue on the 2,900 acres of orchards and vineyards around the lake. Annual gross production from this acreage is in the millions of dollars, so there is little doubt that the modifications of intakes would be worthwhile. The estimated cost of modifying boat launches and docks to operate at lower lake levels is $201,000 while the annual value of recreational boating on Osoyoos Lake is estimated to be $84,000 (Appendix A). Since most of the annual value of boating would be lost without modifications to boat launches and docks, these modifications would be a better alternative to doing nothing in the event of a dam failure.

The estimated costs of modifications to intakes, launches and docks are summarized in Table 3. These were based on a short field survey of installations on Osoyoos Lake and are considered to be rough estimates (Environment Canada, January 1982).

TABLE 3

Cost Estimates for Modifying Intakes, Boat Launches and Docks for Operation at Lower Lake Levels

Item	Cost Estimate
Boat Launches	$ 120,000
Docks	10,000
Intakes	25,000
Contingencies	45,000
Administration, Engineering and Supervision	40,000
Total	$ 240,000

The total cost of $240,000 would be considered as a single savings occurring in the first year if we were certain that the present structure would fail within one year. If we assume less than 100% risk of the structure failing within one year, the $240,000 is distributed over a number of years weighted by the probability of failure in each year.

3. Short Term Losses in the Event of a Dam Failure

Information is limited on the extent of losses which would occur before adjustments could be made to the intakes, boat launches and docks. It is thought that emergency procedures such as dumping fill in the river channel could be used to maintain lake levels temporarily while adjustments to the structures took place. However, if Zosel Dam failed completely, lake levels would drop quickly and there might be a short period when intakes could not operate and boat access would be restricted.

The following assumptions are made:

a) The dam will fail during the freshet, which is in late June.
b) There would be a 10 day period during which irrigation water would not be available. This would result in a 15 percent drop in the cherry crop, 5 percent drop in the peach crop and a 1 percent drop for all other crops.[1]
c) 25 percent of the boating days in the season would be lost due to the time needed for design, contracting and construction of the launches and docks. A value of $2.61 per boating day is used as calculated in Appendix A.

Table 4 summarizes the losses that would take place before modifications could be made to intakes, boat launches and docks.

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1 These estimates were made by the author and are considered to be very rough. Officials at Agriculture Canada indicate that crop loss could vary substantially depending on weather conditions and soil types (Stevenson, 1982).

TABLE 4

Losses Before Modifications Can Take Place
to Intakes, Boat Launches and Docks

Type of Loss	Amount
Reduced cherry crop	$ 174,000
Reduced peach crop	87,000
Reduction in other crops	43,000
Reduction in boating days	21,000
Total	$ 325,000

The total of $325,000 would be considered a single savings occurring in the first year if we assume that the dam will fail within one year. If the risk is less than 100 percent, the $325,000 would be distributed over a number of years weighted by the probability of failure in each year.

4. Losses in Recreational Quality due to Lower Lake Levels

There will be continuing annual losses because of reduced quality of recreational areas at lower lake levels. The two major activities which would be affected are beach use and recreational boating.

a. Losses to Beach Users

The lowering of the lake levels will cause an increase in the distance from the water's edge to the developed beach areas. In some areas the beach users would have to walk an additional 400 feet to reach the water's edge and this is expected to cause a loss in recreational values. It was assumed that the beaches could not be adjusted to accommodate the lower lake elevations since the usual high lake elevations would still be experienced in the freshet. The value of the losses was calculated by estimating the upper and lower bounds and then taking the average of the two.

The minimum value for beach losses was calculated with the assumption that recreationists would stay at their usual beaches despite the exposure of the lake bottom. The losses were then calculated on the basis of the time it would take to walk the extra distance from the developed beach area to the water's edge. It was assumed that this walk would be made twice per beach day. The detailed calculations of these losses are shown in Appendix B. The value of these losses, considered as the lower bound estimate, is shown in Table 5.

The maximum value for the losses was based on the assumption that all users of seriously affected beaches would travel to other less affected beaches. The cost of travel to other beaches plus cost of congestion at the less affected beaches were taken as the maximum value of beach use losses due to lower lake levels. A beach was considered to be seriously affected if the lower lake levels would result in its average width (distance from the water's edge to the inland edge of the beach) increasing to over 120 feet. The 120 feet width was chosen as it is about the average width of major public beaches in other parts of the Okanagan Basin.

The cost of travel to lesser affected beaches was based on rates developed in other studies (see Appendix A, p. 32). The congestion cost was calculated as $.18 per person for every extra 100 people per acre. The cost was estimated by observing current densities at various beaches and computing travel costs between the beaches. It was assumed that the difference in value between a congested beach and a non-congested beach would not exceed the travel cost between the two. The value used is also comparable to the $0.25 estimated by McConnell (1977) in a study of beach congestion. A significant amount of congestion would occur since Osoyoos Community Beach would be the only major beach not significantly affected by a drop in lake levels. Detailed calculations of costs of travel and congestion are shown in Appendix B.

The sum of the travel cost to the less-affected beaches and the cost of congestion was taken as an upper-bound estimate of the value lost in beach recreation. This is shown in the second column of Table 5.

There is a wide range between the lower bound of $17,000 and the upper range of $216,400 for annual losses to beach users. We do not have any information on how many beach users would stay at their present beaches and how many would decide to travel to other beaches. In the absence of this information we assume that half of the beach users would stay at affected beaches and

TABLE 5

Annual Losses to Beach Users

	Lower Bound Estimate	Upper Bound Estimate	Average
Public	$ 2,500	$ 68,200	$ 35,000
Commercial	11,600	119,200	65,400
Residential	2,900	29,000	15,950
Total	$ 17,000	$ 216,400	$ 116,700

that half would travel to other non-affected beaches. The average of $116,700 was taken as an approximation of the annual loss to beach users.

b. Losses to Recreational Boaters

Some recreational value associated with boating would still be lost even if the boat launches and wharves were modified to operate at lower lake levels. The lower lake levels would result in the area south of Haynes Point being cut off from the rest of the lake and a reduced surface area for other parts of the lake. Estimates of resulting recreational losses were made for separate launching areas.

i) South of Haynes Point - This area is served by private launches at a number of resort sites. Boaters from this area generally stay in the south basin and can cross into American water. At lower lake levels they would be cut off from the area north of Haynes Point and would have less lake surface area south of Haynes Point. In total, it is estimated that they would lose 20 percent of their normal boating area. It is assumed that this reduction would result in a 20 percent loss in annual recreational value. It is estimated that there are 4,800 boater days annually in this area of the lake with an annual value of $12,500 based on values calculated in Appendix A. The annual loss would therefore be equal to 20 percent of $12,500, or about $2,500.

ii) Haynes Point Launch Area - Boaters launching from this site generally stay in the lake area south of Osoyoos. They would be cut off from 85 percent of their normal boating area if lake levels were to drop, since they would no longer be able to use the area south of Haynes Point. However, it is expected that these boaters would substitute the north basin for the area south of Haynes Point. This would still result in an estimated 30 percent loss due to decreased lake size and increased costs. The annual losses for the 12,800 boater-days launched from this area would be $10,100.

iii. Osoyoos Marina Launch Area - Most boaters in this area stay in the north basin and so would not be affected by the Haynes Point cut-off. A 10 percent loss in value associated with reduced lake area in the north basin is estimated. With 14,400 annual boater days the annual losses are estimated to be $3,800.

In summary, total annual losses to recreational boating would be $16,400.

5. Stream of Savings over Non-Replacement Alternative

As discussed in section D, the risk of the old structure failing will affect the way savings associated with the new structure are distributed over time. Assuming that risk of failure is 100 percent, then the complete cost of modifications to intakes, boat launches and docks and the cost of short-term losses will represent a savings in the first year of the new structure. The costs due to reduced quality of recreational areas will be an annual savings attributable to the new structure commencing in the first year. This stream of savings over 40 years is shown for the new structure in Table 6.

If the risk of failure is less than 100 percent, the modification costs and short term losses would be distributed over a number of years, weighted by the marginal risk of failure in each year. The annual recreational losses would be weighted by the accumulated probability of failure in each year, as was shown in equation (1).

The present value of the savings are calculated over a range of 10 different risk scenarios of dam failure as shown in Table 7. These savings define a maximum limit to the benefits.

TABLE 6

Savings from New Structure Assuming a 100 Percent Probability of Old Structure Failing

Year	Modification Costs of Intakes, Boat Launches and Docks	Short Term Losses	Reduced Quality of Recreational Boating	Reduced Quality of Beach Recreation	Total
1	$240,000	$325,000	$16,400	116,700	698,100
2	0	0	16,700	118,800	135,500
3	0	0	17,000	120,900	137,900
4	0	0	17,300	123,000	140,300
5	0	0			
6	0	0	increasing by	increasing by	
-	0	0	$300 per year	$2,100 per year	increasing by
-	0	0			$2,400 per year
-	0	0			
-	0	0			
-	0	0			
-	0	0			
-	0	0			
-	0	0			
-	0	0			
-	0	0			
-	0	0			
40	0	0	28,100	198,600	226,700
Present value with interest rate of 10 percent	218,182	295,455	187,064	1,328,003	2,028,704

TABLE 7

Probabilities of Dam Failure with Different Risk Scenarios

Risk Scenario / Year	A	B	C	D	E	F	G	H	I	J
1	1.00	.90	.80	.70	.60	.50	.40	.30	.20	.10
2	0	.10	.10	.10	.10	.10	.10	.10	.10	.10
3	0	0	.10	.10	.10	.10	.10	.10	.10	.10
4	0	0	0	.10	.10	.10	.10	.10	.10	.10
5	0	0	0	0	.10	.10	.10	.10	.10	.10
6	0	0	0	0	0	.10	.10	.10	.10	.10
7	0	0	0	0	0	0	.10	.10	.10	.10
8	0	0	0	0	0	0	0	.10	.10	.10
9	0	0	0	0	0	0	0	0	.10	.10
10	0	0	0	0	0	0	0	0	0	.10
Present Value of Savings ($000)	2,029	2,012	1,980	1,933	1,874	1,802	1,720	1,627	1,524	1,414

F. Analysis of Replacing Zosel Dam at a Later Date

The benefits to Canada will not exceed a certain level at which it becomes more economic to delay construction of the dam. This condition was expressed in equation (4).

(4) $KN \leq p_i\ (AL + BTL + BCL + CI)/r$

where: p_i = probability of dam failure in year i

AL = agricultural losses which would occur before modifications could be made to intakes

BTL = losses to recreational boaters while boat launches are unusable

BCL = losses to beach users due to lower lake levels

CI = costs of modifying intakes to operate at lower lake levels

r = interest rate

This limit is calculated over a range of risk of failure from 10 to 100 percent, as we do not have a quantified estimate of risk of failure. The agricultural losses were estimated at $304,000 as shown in Table 4. Losses to recreational boaters were estimated at $83,500 from Appendix A and the losses to beach users were estimated as $116,700 from Appendix B. The cost of modifying intakes was estimated at $39,000 as discussed in Section E.2. Table 8 shows the limits to the Canadian benefits defined by the condition expressed in equation (4).

TABLE 8

Limit to Maximum Benefit Defined by Optimal Replacement Condition

Current Year Risk of Present Dam Failing	Limit to Maximum Benefit
100%	5,432,000
90	4,889,000
80	4,346,000
70	3,802,000
60	3,259,000
50	2,716,000
40	2,173,000
30	1,630,000
20	1,086,000
10	543,000

G. Determining Maximum Canadian Benefits

The benefits to Canada are limited by the conditions expressed in equation (2) and (4). At each level of risk the benefits are equal to the lesser of the two limits. Table 9 shows the benefits at each risk level.

TABLE 9

Benefits of Replacement Structure to Canada or British Columbia

Current Year Risk of Present Dam Failing	Limit One*	Limit Two**	Maximum Benefits
100%	2,029,000	5,432,000	$ 2,029,000
90	2,012,000	4,889,000	2,012,000
80	1,980,000	4,346,000	1,980,000
70	1,933,000	3,802,000	1,933,000
60	1,874,000	3,259,000	1,874,000
50	1,802,000	2,716,000	1,802,000
40	1,720,000	2,173,000	1,720,000
30	1,627,000	1,630,000	1,627,000
20	1,524,000	1,086,000	1,086,000
10	1,414,000	543,000	543,000

*Limit One = $\sum_{i=1}^{n} C_i/(1+r)^i$ (Equation (2))

**Limit Two = p_i (AL + BTL + BCL + CI)/r (Equation (4))

10% interest rate is used for both limits

H. Non-Quantified Benefits

A number of other possible benefits of a new structure have been advanced by interested parties. However, since a preliminary analysis showed that none of these were of much significance to Canada, no attempt was made to quantify them. These are discussed below.

1. Flood Control Benefits

These were thought to be relatively minor since the new structure would not be able to prevent flood damage caused by the Similkameen river backing up, which is the major source of flood damage. The new structure would, however have a higher release capacity than the present structure and could prevent a portion of the damages that occur at low flood levels. These benefits were not quantified as they were not considered significant.

2. Benefits of Storage and Conservation

The new structure will be able to store an extra-foot of water on Osoyoos Lake for use in drought years. The old structure does not have this capability and has a further problem with leakage. However, it was felt that this extra storage would only be a benefit to the U.S., since it would be used for downstream irrigation in the state of Washington. It was assumed that differences in lake levels due to the extra storage would not provide any significant benefits.

3. Secondary Benefits

Secondary benefits were not quantified although there may be some basis for considering them. If some tourists cease coming to the Osoyoos area because of lowered recreational quality, then some of the accommodation and service capacity may go unused. If this "misplaced" portion of tourist demand is not taken up by slack accommodation elsewhere in Canada then there would be a net secondary loss to the economy. However, there may be current excess demand for tourist accommodation in the Osoyoos area which would take up the excess accommodation left by other tourists leaving. There was no way of estimating the drop in demand for tourist accommodation in the Osoyoos area or the supply-demand conditions for other tourists areas in Canada, so secondary benefits were not considered.

I. Conclusions

The level of benefits to Canada or British Columbia of a replacement dam is highly dependent on the risk of Zosel Dam failing. The benefits are substantial at high levels of risk, but become lower as risk of failure declines. Once the risk of failure is below 30 percent the benefits decline quite sharply. An examination of the present Zosel Dam and an estimate of the risk of its failing should be made in order to arrive at a reliable estimate of the benefits.

This study examined economic benefits to Canada, based on the assumption that the present Zosel dam would fail. It did not look at the question of responsibility for maintaining the present structure and liability for damages that would occur in the event of a dam failure. This question would be relevant to the decision whether or not to commit Canadian funds. The level of benefits to the United States might also be examined in order to be certain that Canada's proportional share of the costs would not exceed its proportional share of the benefits.

It should be noted that this study has a number of weaknesses. In particular, the evaluation of recreational losses due to low lake levels was highly subjective, and changes in the assumptions can have significant effects on the calculated losses. Further refinements in the valuation of recreational losses would not be possible without actually observing the effects of low lake levels on recreationists or else undertaking surveys to ask recreationists to estimate subjectively their loss in user-values.

Sources of data for this study were limited to federal government departments and to information from published documents. This limitation may have reduced the accuracy of some of the data used, particularly data which was gathered from field surveys where limited manpower was available. A more reliable data base might have been provided if consultation had taken place with the State of Washington and the Province of British Columbia.

The study also suffers from a scarcity of data in determining short term losses in the event of a failure of Zosel Dam. These losses may vary substantially from those estimated in the study, depending upon how quickly emergency measures could be implemented in the event of a dam failure. If emergency measures were undertaken immediately after dam failure, then most of the short term losses estimated in this study could be prevented. On the other hand, the actual losses could be much higher than the study estimates if a delay were to occur in undertaking emergency measures.

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APPENDIX A
VALUATION OF RECREATIONAL BOATING

An estimate of the value of recreational boating on Osoyoos Lake was needed to calculate losses that would be associated with lower lake levels. This appendix outlines the methodology and data used to estimate this value.

Methodology

An extension of the Clawson-Knetsch travel cost method was used to estimate the value of recreational boating. This method has two basic steps which are:

A) estimate the relationship between travel costs to the recreational site and the rate of participation from different areas; and,

B) construct a demand curve for recreation at the site by increasing the cost of using the site in increments and calculating numbers of users based on the participation cost relationship in step A.

The Participation Rate Model

The relationship described in step (A) was estimated econometrically using cross section data from 28 regions of origin. Two formulations were used:

$$(1)\ BD_i = f(D_iOS,\ D_iOK,\ D_iNO,\ Y_i,\ PC_i)$$

$$(2)\ BD_i = f(FC_i,\ MC_i,\ D_iOK,\ D_iNO,\ Y_i,\ PC_i)$$

where:

BD_i	=	boating days per 100 population on Osoyoos Lake from region i
D_iOS	=	distance in miles from region i to Osoyoos Lake
P_iOK	=	distance in miles from region i to nearest alternative lake in the Okanagan Basin
D_iNO	=	distance in miles from region i to the nearest alternative lake not in the Okanagan Basin
Y_i	=	per capita income in region i

PC_i = population of the largest city in region i

FC_i = fixed cost of travel to Osoyoos from region i

MC_i = marginal cost of a boating day on Osoyoos Lake for recreationists from region i.

In the first formulation, distance to Osoyoos Lake is used as a proxy for the average cost of a boater day. Some problems arise with the formulation because visitors from distant regions tend to stay longer in the Okanagan and average out the travel costs over a greater number of days. Thus an increase in distance travelled does not necessarily mean an increase in average costs per day of use. An attempt is made to account for this problem when the demand curve is derived in the second stage of the analysis.

In the second formulation, costs are divided into fixed costs of visiting the site and marginal costs per boater day. Fixed costs were considered to be the costs of the return trip to the Okanagan Basin from the region of origin. For boaters who live in the Okanagan Basin, these fixed costs were taken to be zero. The marginal, or daily costs of boating had a number of components including the cost of the return trip from the accommodation in the Basin to the lake, the cost of accommodation, and the extra cost of food for the day. For basin residents, the costs of accommodation and extra food were zero. In cases where residents from other parts of the Basin travelled to Osoyoos Lake for boating it was assumed that these trips were day-trips.

Both formulations included the distance to alternative lakes, regional incomes and the population of the largest cities in the region. The population variable was included to reflect the availability of urban based recreational alternatives.

Participation rate models as in equations (1) and (2) were also formulated for other lake regions in the Basin. This enabled a more efficient joint estimation procedure to be used and allowed comparisons to be made between the different regions.

The regions considered were:

1) Osoyoos Lake
2) Penticton region (Skaha Lake and Okanagan Lake South)
3) Kelowna region (Okanagan Lake Central)
4) Kalamalka Lake

Results of Estimation

Estimates for the participation rate model, as formulated in equation (1), are shown in Table A-1. The model fits the data quite well for all four regions and most explanatory variables have coefficients that are statistically significant. Two of the variables, income and population of largest city in region are not significant.

Estimates for the second formulation in equation (2) are shown in Table A-2. The income and population of largest city were not included in the estimated model, as preliminary estimations showed that they were not significant and did not affect the coefficients of other variables. A dummy binary variable is included for Okanagan residents (i.e. the variable is equal to one for regions within the Okanagan and zero for areas outside the Okanagan). The purpose of the dummy variable was to account for any differences between Okanagan residents and visitors because of such factors as knowledge of the area and ability to use the lakes on weekends and evenings.

As can be seen from the high R^2 values in Table A-2 the marginal cost formulation results in an extremely good fit of the model to the data. The marginal cost, fixed cost and distance to nearest alternative lake in the Okanagan are significant in all equations. The distance to alternative non-Okanagan lakes was not significant in any of the equations.

The dummy variable, while significant in some regions, is not of a

TABLE A-1

*Regression Coefficients for Participation Rate Equations, Distance Formulation

Explanatory Variables / Dependent Variable	Constant	*Distance to Lake Area	*Distance to nearest alternative Lake in Okanagan	*Distance to nearest alternative Lake	Income Per Capital	Population Largest City in Region	R^2
Number of boater-days on Osoyoos Lake per 1000 population	75.8	- 26.58 (-8.54)	6.77 (3.43)	5.70 (2.90)	.002 (0.82)	- .00009 (-0.50)	.75
Number of boater-days in Penticton Region per 1000 population	41.2	- 17.10 (-24.0)	6.52 (9.30)	3.06 (3.35)	.00007 (0.78)	- .0014 (0.16)	.94
Number of boater-days in Kelowna Region per 1000 population	1.21	- 0.56 (-33.30)	.311 (20.53)	0.067 (3.52)	.00001 (.32)	- .000001 (-0.85)	.95
Number of boater-days of Kalamalka Lake per 1000 population	60.9	- 23.9 (-14.8)	11.36 (8.74)	5.49 (3.62)	- .0053 (-0.23)	- .00001 (-0.48)	.82

Estimated by seemingly unrelated regressions, with 28 observations. T-statistics are shown in parenthesis.

* All distances are in natural logarithms

TABLE A-2

Regression Coefficients for Participation Rate Equations, Marginal Cost Formulation

Explanatory Variables / Dependent Variable	Constant	Marginal Cost of boater-day	Fixed Costs* of Travel	Distance to* nearest alternative Lake in Okanagan	Distance to* nearest alternative non-Okanagan Lake	Dummy for Okanagan Residents	R^2
Number of boater-days on Osoyoos Lake per 1000 population	80.36	- 42.42 (-103.32)	- 1.56 (-3.64)	0.46 (2.12)	0.26 (1.54)	36.20 (12.16)	.999
Number of boater-days in Penticton Area per 1000 population	29.71	- 21.07 (24.58)	- 6.61 (-4.56)	6.21 (5.06)	-0.45 (-1.37)	- 12.27 (-1.54)	.996
Number of boater-days in Kelowna Region per 1000 population	97.67	- 61.13 (-43.44)	- 19.49 (-6.97)	16.96 (11.85)	- 0.23 (-0.25)	- 77.37 (-3.81)	.994
Number of boater-days of Kalamalka Lake per 1000 population	51.10	- 30.87 (-19.63)	-4.12 (-1.43)	2.98 (2.76)	0.38 (0.41)	- 1.16 (0.05)	.960

Estimated by seemingly unrelated regressions, with 28 observations. T-statistics are shown in parenthesis.

* Costs and distances are in natural logarithms

consistent sign in the four regions. The dummy variable was also highly correlated with fixed costs which caused difficulties in estimation. When the dummy variable was left out of the equation there was little change in the R^2 and the coefficients of other variables were not affected except for fixed costs.

Despite the good fit of the models, caution should be taken in judging the reliability of the estimates. As mentioned, there is high multicollinearity in the data which makes some coefficients sensitive to different model specifications. The high R^2 values are partly due to the nature of the variation in the dependent variable, participation rate. Participation rates for regions adjacent to lakes are about two orders of magnitude higher than participation rates from other regions. The estimated models have high R^2 values because they predict high participaton rates for regions within the basin and low participation rate for all other regions.

Calculating the Demand Curves

As discussed earlier, demand curves can be constructed using the estimated participation rate models. The procedure is straightforward for the marginal cost model shown in Table A-2. The marginal cost is increased by an increment for each of the 28 regions, and total participation is calculated using the estimated participation rate equation. The marginal cost is increased again and participation is re-calculated. This procedure is repeated until total participation is nil. The increments in marginal cost per boater day are equivalent to admission prices, so a price-quantity demand relationship is obtained.

The procedure for constructing a demand function using the distance formulation of the model estimated in Table A-1 is different from the above procedure, in that distance, rather than marginal cost is incremented. For example, to represent a one dollar increase in the average cost per user day, it would be necessary to increment the mileage by an amount equivalent to one dollar in cost. This procedure becomes complicated with visitors who stay for more than one night, because the travel costs get averaged out over the length of their stay. Thus the length of time spent in the Okanagan will affect the distance increment corresponding to a unit increment in the per day cost at the site. It was assumed that visitors who lived within 90 miles of the site stayed for an average of one day, visitors from 90-250 miles stayed for an average of five days, and visitors from over 250 miles stayed for an average of 10.5 days. These averages were taken from a separate survey of Okanagan tourists (Phipps and James, 1980). Mileage increments corresponding to a unit increase in average per day cost at the site were calculated on this basis. The demand curve was then calculated by incrementing mileage by the determined increments and calculating participation from the model in Table A-1.

The demand curves for boating on Osoyoos Lake, derived from the two models, are shown graphically in Figure A-1.

The Value of Boating

Since the actual market price for using the lakes is zero, the whole area under the demand curves represents the consumer surplus for recreational boating. The total consumer surplus values can be divided by the number of user-days to give an average value per day. The consumer surplus values are shown for the different lake regions in Table A-3.

It was felt that the marginal cost formulation gave more reliable results than the average cost (distance) formulation because of the less restrictive assumptions of the model. The per day values are also more consistent with expectations. The per day values are close for all areas except for Osoyoos which is significantly lower. The low Osoyoos value is reasonable considering the low resident population, the smaller lake size and poorer water quality relative to other regions in the Basin.

In conclusion, a value of $2.11 per user day (1980 dollars) is recommended as the value for boating on Osoyoos Lake. Inflated to 1982 dollars, the value is $2.61 per day. The number of boater days is

FIGURE A-I DEMAND FOR RECREATIONAL BOATING ON OSOYOOS LAKE

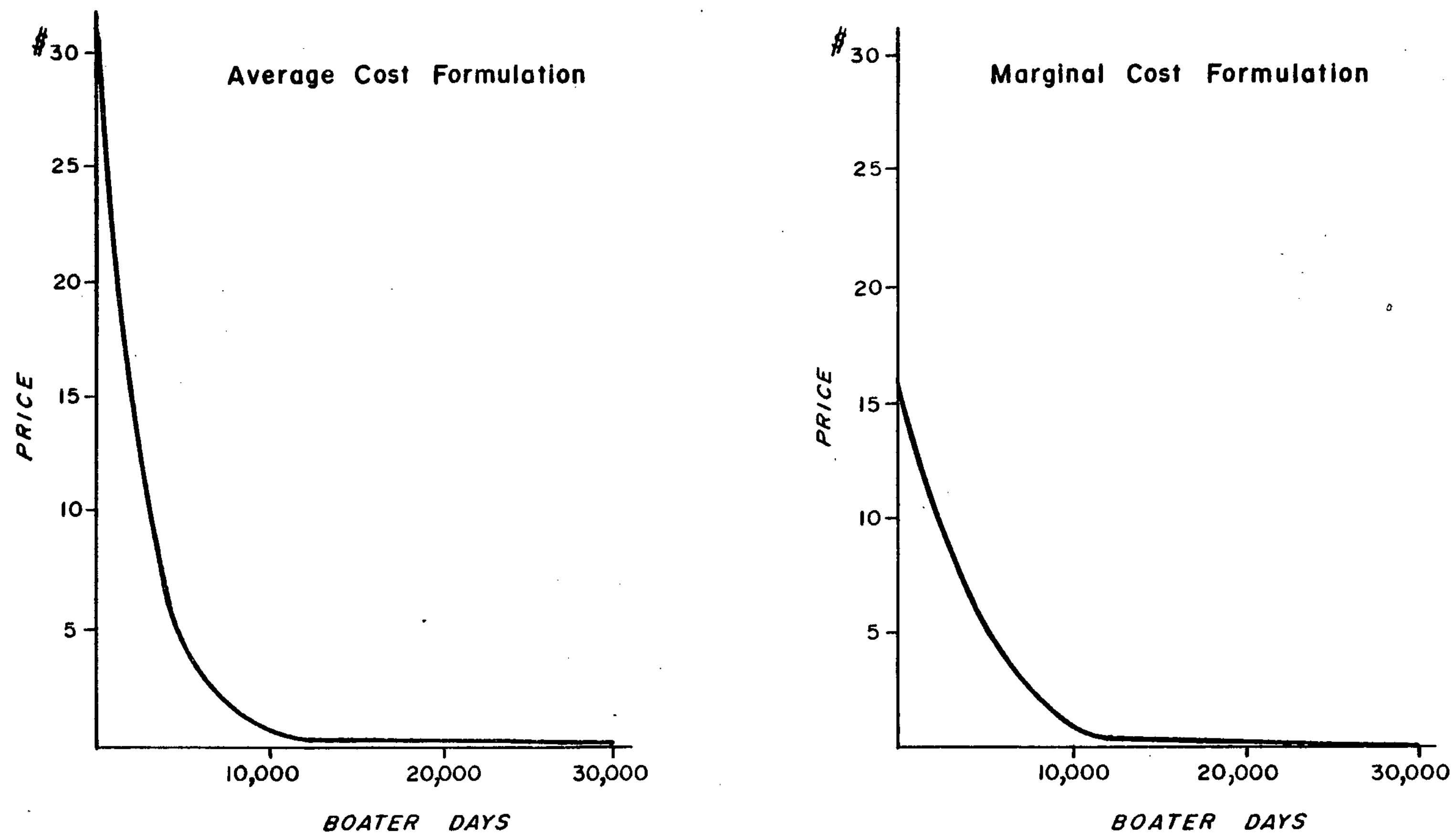

TABLE A-3

Consumer Surplus Values of Recreational Boating in the Okanagan in 1980

	Distance Formulation		Marginal Cost Formulation	
	Total Value Per Year (1980$)	Value Per Day	Total Value Per Year	Value Per Day
Osoyoos	$ 84,000	$ 2.80	$ 63,300	$2.11
Penticton	254,000	3.77	299,700	4.44
Central Okanagan	306,000	2.11	654,000	4.51
Kalmalka	132,000	3.77	172,600	4.93

estimated to have increased from 30,000 in 1980 to 32,000 in 1982 giving a total value of $83,500 for recreational boating in 1982.

Data Sources

1) Total Boater Days per Lake Region

These were estimated from aerial counts made by the Fish and Wildlife Branch of the B.C. Ministry of Environment (1980). Three spot counts were done on each day for a 30-day sample over the May to October period. These spot counts were then increased by a factor reflecting the full length of the season, daily hours of use and number of people per boat. The following totals were estimated.

Region	Boater Days (1980)
Osoyoos	30,000
Penticton	67,500
Kelowna	145,000
Kalamalka	35,000

2) Points of Origin for Boaters

This information was obtained from data gathered in the "Okanagan

Boat Launch User Survey" carried out by the Parks Branch of the B.C. Ministry of Lands, Parks and Housing (1979). The regions of origin were classified under B.C. regional districts, Alberta (one region) rest of Canada (one region) and the U.S. (one region). The survey also provided information on number of people per boat and other activities participated in by the boaters while in the Okanagan. Altogether 11,727 parties were surveyed at major boat launches in each region. Because of the large sample size it is felt that the results of the survey are quite representative of the boating population. The number of boaters from each point of origin is calculated by multiplying the relative distribution from the sample times the total boater day estimates.

Travel Costs

It was assumed that all boaters travelled to the Okanagan by automobile. The cost per mile was calculated in the following manner:

Travel Cost Calculations		Cost per Mile (1980 dollars)
car cost per mile based on 1980 federal government rates		22¢
per person cost for average party size of 3.15		.22/3.15=.07
time cost per person assuming 50 MPH at a cost of $1.65 per hour. $1.65 is based on average of 1/4 the average industrial wage for adults and 1/12 for children*		1.65/50 = .033
	Total	.103
data indicates that boaters spent 62% of their days in the Okanagan boating and 38% of their days on other activities. To get travel costs associated with boating multiply by .62		.62 x .103 = .064

* Guidelines suggested by Cesario in "The Value of Time in Recreation Benefit Studies" Land Economics Vol. 55 No. 1 Feb. 1976.

Distances to the Okanagan centres from different regional districts were taken from standard travel maps. Alberta visitors were assumed to have started from a point halfway between Calgary and Edmonton. Visitors from other provinces were assumed to have started from a point halfway between Regina and Winnipeg. A slight increment in mileage was added to distances from Vancouver Island to the Okanagan account for the ferry costs.

Accommodation and Food Costs

There was no direct information on the amount boaters spent on these items, but it was assumed that they had the same expenditure patterns as the general tourist population in the Okanagan. Average accommodation costs were obtained from B.C. Ministry of Tourism "Accommodation and Campground Directory" (1980).

Expenditures on food were obtained from data in Water Based Recreation in the Okanagan Basin (Canada-British Columbia, 1974) and inflated to 1980 terms. Only expenditures on food over what would have been spent at home were included.

Accommodation and food costs were calculated for recreationists in four regions of the Basin. In 1980 dollars, the daily cost per person was calculated to be $6.78 in the Osoyoos region, $7.50 in the Penticton region, $8.38 for the Kelowna region and $7.30 for the Vernon Region.

Income and Population

Per capita regional incomes were based on estimates from Trade and Commerce Magazine (1977). Population data for B.C. were obtained from B.C. Ministry of Municipal Affairs (1980). Population data for Alberta and the rest of Canada were obtained from Statistics Canada.

APPENDIX B
LOSSES TO BEACH-USERS

1) Effect of Low Lake Levels

A field survey was carried out in order to determine the effects of lowering the lake levels on beach areas (Environment Canada, May 1982). Estimates were made on the amount of lake bottom that would be exposed at the new lake levels. It was found that areas on the east side of the lake and Haynes Point were the most seriously affected. The main public beach (Community Beach) and Legion Public Beach, both on the west side, were judged to be not seriously affected. Table B-1 shows the effects of a drop in lake levels on the beach areas.

2) Number of Beach-Users

The number of people at each beach was obtained using two different methods. For public beach areas, counts were made as part of the Okanagan Basin Implementation Agreement (Phipps and James, 1980). For commercial resort areas, beach days were calculated on the basis of accommodation available in the resorts. It was assumed that each person-unit of accommodation represented 60 beach-days. Accommodation figures were taken from the British Columbia Ministry of Tourism (1980). For private beach-users, beach days were calculated on the basis of 180 days for each household on the water front.

Table B-2 gives Beach days for the Osoyoos Lake area.

TABLE B-1

Effect of Low Lake Levels on Beach Areas*

Beach Area	Normal Beach Width[1]	Beach Width at Low Lake Levels[2]
East Side Resorts, South Basin	25 - 40'	150'
Van Acres Resort, North Basin	20'	750'
Commercial Beach Strip, North Basin	40'	250'
Haynes Point Beaches	10 - 15'	300'
East Osoyoos Public Beach	65'	400'
Osoyoos Community Beach	25'	65'
Osoyoos Legion Beach	40'	65'

1. Normal beach width refers to width of sandy area at 911' lake elevation.

2. Width at low lake levels refers to distance from inland edge of beach to waters edge when lake levels are 908' north of Haynes Point and 906' south of Haynes Point.

*Data source; field survey (Environment Canada, May 1982)

TABLE B-2

Beach Days in the Osoyoos Lake Area in 1980

Beach Area	Beach Days
Private Residential	36,000
Osoyoos Community Beach	46,000
East Osoyoos Beach	15,000
Osoyoos Legion Beach	8,000
Haynes Point	9,000
East Side Resorts	78,000
Van Acres Resort	32,000
Commercial Beach Strip	77,000

3. Losses to Beach-Users

The lower bound estimate of losses to beach users was calculated on the basis of the time it would require to walk the extra distance to the waters edge at the lower lake levels. It was assumed that this walk would be made twice per beach-day. The costs of time were the same as those used in Appendix A. Table B-3 gives the lower bound estimate for each beach area.

TABLE B-3

Lower Bound Estimates for Annual Losses to Beach Users

Beach	Total Extra Distance Walked	Extra cost
Private Residential	775 feet	$2,900
Community Beach	0 feet	0
East Osoyoos Beach	1,120 feet	1,750
Legion Beach	0 feet	0
Haynes Point	800 feet	750
East Side Resorts	120 feet	835
Van Acres Resort	2,170 feet	7,195
Commercial Beach Strip	520 feet	3,575
Total		$17,005

In order to calculate an upper bound estimate for beach losses it was assumed that all users from seriously affected beaches would travel to Community Beach, where the effect of lower water levels would not be severe. Travel costs were calculated according to the rates used in Appendix A. Congestion costs were calculated on the basis of $0.18 per extra 100 people per acre. This figure was arrived at by examining the current densities of use at the commercial beach strip and Community Beach and comparing the difference in density to the travel costs between the ten areas. Table B-4 gives the travel and congestion costs for each beach area.

The average of the lower and upper bound estimates was chosen to represent the "most likely" value of losses to beach users. This value is equal to $116,700 annually.

TABLE B-4

Upper Bound Estimate of Annual Losses to Beach Users

Original Beach Area	Distance to Community Beach (Miles)	Travel Costs $	Congestion Costs $	Total Costs $
Private Residential	1.9	15,010	13,980	28,990
Community Beach	0	0	40,005	40,005
East Osoyoos Beach	.7	3,240	13,045	16,285
Legion Beach*	.5	0	0	0
Haynes Point	2.1	4,082	7,820	11,902
East Side Resorts	1.8	30,145	16,598	46,743
Van Acres Resort	1.0	6,912	6,809	13,721
Commercial Beach Strip**	.5	42,250	16,498	58,748
Total Costs		$101,639	$114,755	$216,394

* Not affected by low lake levels

** It is assumed that recreationists who originally went to this beach area would walk to Community Beach. All other recreationists are assumed to drive to Community Beach.