OKANAGAN BASIN IMPLEMENTATION AGREEMENT

WORKING REPORT

SUMMARY OF NITROGEN AND PHOSPHORUS LOADINGS TO THE OKANAGAN MAIN VALLEY LAKES FROM CULTURAL AND NATURAL SOURCES

by

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ABSTRACT

As part of the Okanagan Basin Implementation Agreement nutrient loadings to the main valley lakes were updated to indicate changes in loadings that had taken place since 1970 and to identify the current major sources of nutrients for management control purposes. Phosphorus loadings, the nutrient of greatest concern with respect to lake management in the Okanagan are discussed with regard to trends and changes in lake quality in the Report on the Okanagan Basin Implementation Agreement.

This report summarizes the nitrogen and phosphorus loadings to the lakes from the different sources and details the methods by which the loading estimates were produced for sources where this information is not reported elsewhere. For this reason this report concerns mainly the determination of loadings from municipal and industrial sources and natural watershed sources; the calculation of total loadings to Osoyoos Lake; the application of results from other studies to estimate bioavailable loadings from watershed sources and methods of projecting loadings to 1990. Finally, the uncertainty and limitations of the loading estimates are discussed to assist the reader in interpreting the results.

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INTRODUCTION

Nutrient enrichment and the effects of increased plant and algal growth on water-based recreation continues to be one of the major concerns of water quality management in the Okanagan main valley lakes (1). Control of the major nutrient phosphorus is recommended to maintain or reduce lake productivity as required.

Phosphorus inputs to the main valley lakes were updated as part of the Okanagan Basin Implementation Agreement Review of Framework Plan and compared to 1970 estimates for the following reasons: 1) to monitor the effects of measures to control loadings (e.g. tertiary treatment of effluent from the City of Penticton); 2) to indicate the extent of control programs required by demonstrating trends in loadings; and 3) to show locations of major loadings, particularly from non-point sources, for priorizing management control programs.

The loading update consisted of: 1) the determination of current (1980) loadings from the various sources to each of the main lakes; 2) the summary of total loadings from all sources to each of the lakes; 3) an estimate of the percentage of phosphorus loading available for plant and algal uptake; and 4) projections of current loadings to 1990.

The purpose of the present report is to describe methods for components of the update that are not reported elsewhere. This content includes the determination of loadings from municipal and industrial sources and natural watershed sources; the calculation of total loadings to Osoyoos Lake; the application of results from other studies to estimate bioavailable loadings from watershed sources and methods of projecting loadings to 1990. Finally, the uncertainty and limitations of the loading estimates are discussed to assist the reader in interpreting the results. A listing of reports for each review component is set out in Table 1.

TABLE 1

LIST OF REFERENCES FOR DETERMINATION OF NUTRIENT LOADS TO THE OKANAGAN MAIN VALLEY LAKES

COMPONENT	REFERENCE
1. Estimate of Loadings from Source	
Point Sources	
(a) Municipal and industrial	Present Report
(b) Storm Sewer	(2)
Non-Point Sources	
(a) Agriculture, septic tanks and other sources (Other sources include industrial, effluent to ground disposal, domestic fertilizer and pets)	(3)
(b) Logging	(4)
(c) Dustfall and precipitation	(5)
(d) Natural watershed sources	Present Report
(e) Mainstem loadings	Present Report
2. Organization of Individual Source Loadings to Determine Total Loadings to Lake	Present Report
3. Bioavailability of Loadings	(6)
4. Loading Projections	Present Report

The results presented deal primarily with phosphorus loading since it is the nutrient recommended to be controlled. Some nitrogen loads are shown for information purposes, and are included in most reports set out in Table 1.

1. PHOSPHORUS LOADING ESTIMATES

Point Sources

Phosphorus loadings for the period 1976-77 for the major municipal treatment plants in the Okanagan are reported in (7). Loadings were updated for most plants on the basis of effluent concentration and flow data collected by plant operators and Waste Management Branch (WMB) personnel during 1979 and 1980. Table 2 sets out the annual loads for each of the centers, as well as mean annual concentration and mean annual flow. The 1976-77 loads are shown in brackets. The number of measurements taken varied considerably for each of the sites as indicated in Table 2.

TABLE 2: ESTIMATED ANNUAL LOADING OF TOTAL NITROGEN AND TOTAL PHOSPHORUS FROM MUNICIPAL DISCHARGES DURING 1979-80

DISCHARGE	MEAN ANNUAL FLOW $m^3/yr.x10^3$	NO. OF CONCENTRATION SAMPLES COLLECTED ANNUALLY	MEAN CONCENTRATION			ESTIMATED ANNUAL LOADING (kg/yr)*2	
			Total Nitrogen	Total Phosphorus	Dissolved Phosphurus	Total Nitrogen	Total Phosphorus
Armstrong	300	3-5	19.3	5.1	3.7	5,500 (5,100)	1,500 (1,300)
Vernon						Land Disposal	
Kelowna	2,900	16-20	19.9	3.5	2.9	66,000 (51,800)	14,000 (11,400)
Westbank	230	1-2	36	6.4	5.9	8,400	1,500
Penticton	3,200	20-80	26.3	0.9	0.5	80,700 (106,000)	2,400 (2,800)
Oliver	220*1	4-6	12.8	3.5	3.0	3,000 (2,500)	900 (1,000)
TOTAL ANNUAL LOADING FROM MUNICIPAL SOURCES:						164,000	20,300

*1 Flow may require correction due to faulty meter.

*2 Measured loadings for 1976-77 (7) are shown in brackets.

In the case of data for the Kelowna plant, total phosphorus concentrations were estimated using orthophosphorus concentrations and the ratio of orthophosphorus to total phosphorus for those periods for which both data were available since orthophosphorus data were more numerous. Final annual total loading estimates were adjusted to reflect the increase in flows to the treatment plant since 1976-77. Annual loadings are based on the sum of loadings from the smallest time increment for which concentration data and flows were available. This time increment varied from weekly for total phosphorus at Penticton to semi-annually at Westbank.

Loadings from industrial sources were more difficult to determine in that the number and location of plants discharging to receiving waters had to be determined as a first step. This inventory of industrial sources was carried out by reviewing the list of discharges for 1970 (8) with WMB staff and determining changes to the list due to closures and changes in treatment methods, and the addition of more recent discharges. Plants with cooling water discharges only were not necessarily listed since the contribution of nutrients from cooling water is assumed to be negligible. Also, dairy farms were not included since they are considered separately under non-point sources. Tables 3 to 5 list the current discharges and include the method of waste disposal. As shown, most industries now, discharge to ground through exfiltration, septic tank tile fields or irrigation of crops; or to municipal treatment plants. All major industrial discharges currently receive some form of treatment. Sources discharging to ground are addressed in a separate report (3). As noted, only the Brandt's Creek Trade Waste Treatment Plant (BCTWTP) and the Ministry of Environment, Summerland Fish Hatchery, are significant discharges to receiving water.

Annual loadings for these discharges (Table 6) were calculated from WMB data. Water supply (influent) loads of nitrogen and phosphorus to the Summerland Hatchery are also indicated to allow the separation of loads directly attributable to hatchery operations (net loading). Apparent is the large contribution of nitrogen from the groundwater supply to the hatchery.

Phosphorus inputs due to storm sewers were estimated for the Okanagan centers of Penticton, Kelowna and Vernon (2) using a model relationship. These loadings are estimated for the area of storm sewer development for each center as of 1978. Since the total input from storm sewers is small in comparison to other sources the increase in loadings from 1978 to 1980 is assumed to be insignificant in terms of total loadings to the lakes.

Non-Point Sources

The major thrust of updating non-point sources concerned mainly the cultural sources such as agriculture, septic tanks and other sources (3) since most of these sources can be identified easily and feasibly controlled. The update was accomplished by the same accounting procedure used in the 1970 loading estimates. The procedure involved multiplying potential loadings from an identifiable non-point source (e.g. fertilizer application on agricultural land) by an experimentally derived transmission coefficient which reduced the potential loading in accordance with horizontal and vertical attenuation of nutrients. However, a large percentage of non-point loadings occur from so called watershed sources that include primarily natural sources. Separation of effects of sources such as cattle grazing and other extensive cultural activities from natural sources has not been possible with the exception of loading due to logging and associated road building which is reported elsewhere (4). Discussion of loading from watershed sources thus represent the composite of a number of sources that cannot be quantified separately.

TABLE 3: 1980 UPDATE OF MAJOR INDUSTRIAL DISCHARGES INVENTORIED DURING THE OKANAGAN BASIN STUDY (1972)

	FIRM	LOCATION	OPERATION	TREATMENT OF PROCESS AND WASTEWATER	CHANGE SINCE 1972	EXISTING DIRECT DISCHARGE TO SURFACE WATER
1.	Monashee Co-op	Osoyoos	Fruit packing	Septic tank system.	Operation of septic tank - tile field.	
2.	Oliver-Osoyoos Co-op	Oliver	Fruit packing	Effluent treated at Oliver STP.	Connection to STP.	
3.	Canadian Canners Ltd.	Penticton	Fruit processing and canning	Effluent treated at Penticton STP.	Connection to STP.	
4.	Lakeshore Bottling Co.	Penticton	Soft drink bottling	N/A	Out of Operation	
5.	Fish and Wildlife Hatchery	Summerland	Fish culture	Sedimentation and sludge removal.	Sedimentation ponds since 1972.	Okanagan Lake.
6.	Cornwall Canners Ltd.	Summerland	Fruit Canning	N/A	Out of operation.	
7.	American Can. of Canada (McDonald's Consolidated)	Kelowna	Fruit processing	Effluent treated at Brandts Cr. Trade Waste Treatment Plant.	Operation of Trade Waste Treatment Center.	Treated effluent to Brandts Creek.
8.	Okanagan Beverage and Calona Wines	Kelowna	Bottling, winery	Effluent treated at Brandts Cr. Trade Waste Treatment Plant.	Operation of Trade Waste Treatment Center.	Treated effluent to Brandts Creek.
9.	Kelowna Growers Exchange and Sun Rype #2	Kelowna	Canning	Effluent treated at Brandts Cr. Trade Waste Treatment Plant.	Operation of Trade Waste Treatment Center.	Treated effluent to Brandts Creek.
10.	Kelowna Beverages and Okanagan Packers	Kelowna	Bottling and canning	Effluent treated at Brandts Cr. Trade Waste Treatment Plant.	Operation of Trade Waste Treatment Center.	Treated effluent to Brandts Creek.
11.	Kelowna Growers Co-op (formerly B.C. Orchards Co-op)	Kelowna	Fruit packing	Effluent treated at Brandts Cr. Trade Waste Treatment Plant.	Operation of Trade Waste Treatment Center.	Treated effluent to Brandts Creek.
12.	Vernon Fruit Union	Vernon	Fruit packing	Ground disposal.		
13.	Fraser Valley Milk Producers Assoc. - Dairyland (formerly Dutch Dairies Ltd.)	Armstrong	Dairy products	Effluent treated at Armstrong Sewage Treatment Plant.	Connection to sewage treatment plant.	
14.	NOCA Dairies Ltd.	Vernon	Dairy products	Cooling water and waste from loading dock and catch basin to Vernon Creek.	No change.	

TABLE 4: 1980 UPDATE OF REMAINING DISCHARGES INVENTORIED DURING THE OKANAGAN BASIN STUDY (1972)

	FIRM	LOCATION	OPERATION	TREATMENT OF PROCESS AND WASTEWATER	CHANGE SINCE 1972	EXISTING DIRECT DISCHARGE TO SURFACE WATER
1.	Oliver-Osoyoos Co-op	Osoyoos	Fruit packing	Treatment at Village of Osoyoos facilities.	Connection to sewage treatment system.	
2.	Haynes Co-op	Oliver	Fruit packing	Ground disposal.	No change.	
3.	Sun-Rype Products	Oliver	Fruit packing	Treatment at Oliver STP.	Connection to STP.	
4.	B.C. Tree Fruits (formerly McLean and Fitzpatrick)	Oliver	Fruit packing	Treatment at Oliver STP.	No change.	
5.	Oliver-Osoyoos (Co-op)	Kaleden	Fruit packing	Cooling water only.	No change.	
6.	Penticton Sawmills	Penticton	Log sorting	N/A.	Out of operation.	
7.	Lake Area Growers Co-op (formerly Pyramid Co-op)	Penticton	Fruit packing	Treatment at Penticton STP.	No change.	
8.	Summerland Sweets	Summerland	Fruit processing	Disposal to land.	No change.	
9.	Naramata Co-op	Naramata	Fruit packing	Ground disposal.	Disposal to ground (previously discharged to Okanagan Lake).	
10.	Barkwills	Summerland	Fruit processing	Disposal to land (cooling water to Eneas Creek).	No change.	
11.	Milne Cannery	Summerland	Fruit processing	Disposal to land.	No change.	
12.	Lake Area Co-op	Summerland	Fruit packing	Ground disposal.	No change.	
13.	Westbank Co-op	Westbank	Fruit packing	N/A.	Out of operation.	
14.	Westbank Orchards	Westbank	Fruit packing	Process water to Westbank Irrigation Sewage System.		
15.	Crown Zellerbach (formerly S.M. Simpson)	Kelowna	Sawmill and plywood plant	No discharge of process water.	No change.	
16.	Cascade Co-op	Kelowna	Fruit packing	No discharge (recycle cooling water).	No change.	
17.	Calona Distilleries	Rutland	Distillery	Brandts Creek Trade Waste Treatment Plant (TWTP).	Relocated to Kelowna (waste now treated to TWTP).	
18.	McLean & Fitzpatrick	Rutland	Fruit packing	Process water to ground.	Improvements to collection system and tile fields since 1972.	
19.	Kelowna Growers Exchange	Rutland	Fruit packing	Ground disposal. Discharged cooling water only.	Process water no longer.	
20.	Kelowna Growers Exchange	Kelowna	Fruit packing	Cooling water only.	No change.	
21.	Hiram Walker & Sons	Winfield	Distillery	Ground disposal.	No change.	
22.	Vernon Fruit Union	Oyama	Fruit packing	Process water to ground.	No change.	
23.	R.H. MacDonald	Vernon	Fruit packing	Cooling water only.	No change.	
24.	Hydra Estates Ltd. (formerly Bulamns Products Ltd.)	Vernon	Fruit packing	Cooling water only.	No change.	
25.	Crown Zellerbach	Armstrong	Sawmill	Process and log vat waters to ground disposal.	No change.	

TABLE 5: ADDITIONAL INDUSTRIAL DISCHARGES SINCE THE OKANAGAN BASIN STUDY (1972)

FIRM	LOCATION	OPERATION	TREATMENT OF PROCESS AND WASTEWATER	EXISTING DIRECT DISCHARGE TO SURFACE WATER
1. Ministry of Environment	Penticton	Fish culture	No treatment.	Penticton Creek.
2. Brandts Creek Trade Waste Treatment Plant	Kelowna	Secondary treatment of industrial (mainly food processing) waste		Brandts Creek.
3. Ministry of Environment	Kelowna	Fish culture	Sedimentation pond.	Mission Creek.
4. Claremont Wines Ltd.	Peachland	Winery	Ground disposal.	
5. McLeods By-Products	Armstrong	Meat rendering plant	Ground disposal.	
6. Grandview Produce Ltd.	Armstrong	Potato processing	Ground disposal.	
7. Ranchland Packers	Lavington	Abatoir	Ground disposal.	
8. Golden Valley Wines	Westbank	Winery	Ground disposal.	

TABLE 6: NITROGEN AND PHOSPHORUS LOADINGS FROM THE ONLY MAJOR SOURCES OF DIRECT INDUSTRIAL DISCHARGES TO RECEIVING WATER

	Mean Annual Flow $M^3/yr x 10^3$	No. of Samples Collected Annually		Mean Annual Concentrations (mg/l)		Annual Loadings (kg/yr)	
				Total Phosphorus	Total Nitrogen	Total Phosphorus	Total Nitrogen
1. Brandts Creek Trade Waste Treatment Plant	250	40		0.4	6.4	700	3,500
2. Summerland Hatchery	1,500	4-6	Influent:	0.01	6.2	neg.	9,300
			Effluent:	0.2	7.7	350	11,000
			Net loading from hatchery:			350	1,700
			Total from Industrial:			1,100	5,200

neg. - negligible

The original estimates of loadings from watershed sources in 1970 [termed natural (8)] were compared with loadings calculated from water quality monitoring in a number of locations in the Okanagan over the last five years. As shown in Table 7 the difference between measured and predicted loadings varied from 54-81%. Most of the difference occurs due to the failure of the original estimates to consider phosphorus associated with the suspended sediment load since the difference apparently occurs during periods of higher flows and increased erosion.

TABLE 7

COMPARISON OF PREDICTED PHOSPHORUS LOADINGS
AND MEASURED LOADINGS FROM NON-POINT SOURCES

Tributary Basin	kg/yr MEASURED LOADINGS	kg/yr PREDICTED*[5] LOADINGS	kg/yr DIFFERENCE	PERCENTAGE DIFFERENCE
1. Okanagan River (Skaha Lake outlet to 2 km N. Osoyoos Lake)	29,000[1]	13,300	15,700	54
2. Shingle/Shatford Creek (upstream Water Survey of Canada Station 08NM150)	4,500[2]	900	3,600	80
3. Vaseux Creek (upstream Water Survey of Canada Station 08NM171)	1,100[3]	400	1,700	81
4. Coldstream Creek (upstream Water Survey of Canada Station 08NM179)	2,900[4]	1,200	1,700	59

1 Mean of annual loads measured from 1978-1980 (9).

2 1980/81 (10)

3 1980/81 (4)

4 Based on Waste Management Branch data, Ministry of Environment, for the period 1976-1978 and hydrology data for a similar period from Water Survey of Canada records.

5 Based on the sum of all upstream sources of nutrients. Point sources (Oliver Sewage Treatment Plant) have been reported earlier in this report. Non-Point loadings from cultural sources for 1980 are reported in (3) and 1970 natural loading estimates are reported in (8).

As a result of the above comparison, loadings for 1980 had to be increased to levels above those estimated by the model to reflect loadings due to erosion. These erosional loadings from the watershed were estimated on the basis of extrapolation of measured inputs from selected tributaries with the least development (6) to remaining areas of the Okanagan. Loadings were calculated from approximately 6 to 8 samples collected during 1980 and 1981 and the 10-year average hydrology from Water Survey of Canada records. Areal phosphorus and nitrogen loadings (Table 8) were then calculated for each station based on the area of the sub-basin sampled. Because of the very limited sampling these estimates must be considered preliminary.

TABLE 8

AREAL PHOSPHORUS AND NITROGEN LOADS FOR SELECTED OKANAGAN TRIBUTARIES

TRIBUTARY SUB-BASIN	AREAL LOADING KG/HA/YR	
	Total Phosphorus	Total Nitrogen
1. Vernon Creek (upstream Ellison Lake)	.05	.49
2. Mission Creek	.23	.72
3. Lambly Creek	.08	.57
4. Vaseux Creek	.08	.49

The means of these areal loadings (0.11 and 0.57 kg/ha/yr for phosphorus and nitrogen, respectively) were used to calculate watershed loads for the Okanagan as shown in Table 9.

TABLE 9

ESTIMATES OF PHOSPHORUS AND NITROGEN LOADS FROM WATERSHED SOURCES TO THE OKANAGAN MAIN VALLEY LAKES

LAKE SUB-BASIN	ANNUAL LOADINGS KG/YR	
	TOTAL PHOSPHORUS*	TOTAL NITROGEN
Wood	1,400	12,100
Kalamalka	4,900	28,000
Okanagan	46,000	346,000
Skaha	7,500	48,800
Osoyoos	11,600	81,000
TOTAL FOR THE OKANAGAN BASIN:	71,400	516,000

* Corrected for loadings from forestry activities.

Total phosphorus loading estimates from forestry activities were subtracted from phosphorus loadings reported in Table 9. Loading estimates from forestry activities were calculated based on sampling in Shingle and Vaseux Creeks over one year during 1980-81 and extrapolation of these results to other areas of the Okanagan based on an inventory of logged areas as set out in (4).

Current estimates from watershed sources are a first approximation and, consequently, are the most uncertain of all estimates in the update due to a lack of field data and the problem of extrapolating these limited data from selected watersheds to the entire Okanagan Basin. Notwithstanding, current estimates are thought to reflect the total contribution of phosphorus from watershed sources better than the 1970 estimates, at least for the years for which measurements are available.

Estimates of nutrient loadings from main lakes upstream are set out in Table 10. Loadings from Okanagan Lake to Skaha were calculated from data set out in reference report 11. Loadings from Skaha to Osoyoos were calculated from data set out in reference report 12.

Loadings to Okanagan Lake from Kalamalka Lake and to Kalamalka Lake from Wood Lake, were calculated from nutrient concentration data collected in a separate study (6) and Water Survey of Canada hydrology data.

TABLE 10

NITROGEN AND PHOSPHORUS LOADINGS FROM UPSTREAM MAINSTEM LAKES* :

LAKE SUB-BASIN	ANNUAL LOADING IN KG/YR	
	TOTAL PHOSPHORUS	TOTAL NITROGEN
Wood to Kalamalka	360	3,800
Kalamalka to Okanagan	150	5,600
Okanagan to Skaha*1	3,300	66,000
Skaha to Osoyoos*2	9,400	166,000

* Includes Wood, Kalamalka, Okanagan, and Skaha Lakes.
*1 Reference Report 11.
*2 Reference Report 12.

2. Summation of Total Loadings from All Sources

Loadings were calculated by summation of the loadings in Tables 2, 6, 9 and 10 after they had been converted to bioavailable nitrogen and phosphorus as described below. In most cases this is straight forward. For example, the total for Okanagan Lake includes the three major basins. However, for Osoyoos Lake there is a choice of two methods. The first consists of using the measured loadings for the Okanagan River at a point 2 km upstream of Osoyoos Lake (9). It is assumed that this loading includes sources upstream of Osoyoos Lake with the exception of groundwater inputs. Remaining sources in the Osoyoos Lake sub-basin are summed in the usual manner and included with the Okanagan River loading to produce a total loading to Osoyoos Lake of approximately 35,000 kg/yr. The second method ignores the loadings measured from the Okanagan River and is based on summing the estimates for point and non-point sources downstream of Skaha Lake as well as those in the Osoyoos Lake sub-basin. This estimate is 29,000 kg/yr. The two estimates differ by approximately 20% which may be partly explained because of year to year changes in hydrology which affect the first estimate. The second estimate is more representative of an "average" year for reasons discussed in Appendix "A." The second method and estimate are used in Table 15 because it provides a better separation of controllable and non-controllable sources for management planning and control of sources. Separation of sources upstream is not possible with the loading values for the Okanagan River stations.

TABLE 11

CLASSIFICATION OF TRIBUTARIES ON THE BASIS OF MEASURED AND ESTIMATED BIOLOGICALLY AVAILABLE PHOSPHORUS LOADINGS

Measured Tributaries*[1]	Biologically Available Phosphorus (as a percentage of total phosphorus load)	Unmeasured Tributaries with Similar Characteristics
Deep	95	Westbank, Brandt's
Vernon (upstream Ellison Lake and Okanagan Lake)	75	Kelowna, Oyama, BX, Eneas
Lambly	65	Powers, Trepanier, Peachland, Whiteman, Shorts
Equesis, Shingle, Vernon (upstream Wood Lake)	60	Park Rill, Nashwhito
Coldstream, Vaseux	50	Penticton, Inkaneep, Bellevue
Mission	40	Ellis
	30	Shuttleworth
Trout	15	

*[1] National Water Research Institute study of nutrient composition (6).

The second problem, that of separating loadings due to watershed sources only, was addressed by summing the estimated watershed loadings for each tributary sub-basin determined as explained in the above paragraph and calculating the ratio of watershed to total loadings estimated for each lake sub-basin. Lake sub-basin BAP was then multiplied by this ratio to calculate BAP attributable to watershed sources only. Finally, as shown in Table 12 total phosphorus loadings from watershed sources were adjusted to reflect BAP loadings based on the revised BAP estimates.

3. Bioavailability of Phosphorus

Phosphorus loading in the past overestimated phosphorus available for algal uptake in the lakes because the amount of unavailable phosphorus such as apatite phosphorus was not known. In the current update bioavailable phosphorus (BAP) loading was estimated based on a study carried out in selected tributary sub-basins by the National Water Research Institute of Environment Canada (6). Bioavailable phosphorus is assumed to include all dissolved organic and inorganic phosphorus; all particulate organic phosphorus and non apatite forms of particulate inorganic phosphorus. Details regarding the use of these data to calculate BAP loading are set out below.

As a first approximation it was assumed that point source phosphorus loadings and most non-point phosphorus of cultural origin such as septic tanks and agriculture were available. Loadings from forestry activities as BAP are set out in a separate report (4). Loadings from dustfall and precipitation were assumed also to be totally available. Assumptions regarding complete bioavailability from these sources probably indicates an overestimate of BAP due to, for example, phosphorus associated with dust particles that is largely unavailable in BAP estimates from dustfall.

Loadings from mainstem and watershed sources were changed to indicate BAP as set out in Table 15. Mainstem loading was changed based on the percentage BAP measured for each of the lake outlets (6). However, estimating BAP from watershed sources was more complex. The problems concerned: 1) the incomplete record of BAP for tributaries in the Okanagan since less than half of Okanagan tributaries had actually been measured; and 2) separation of watershed source BAP from BAP for all upstream sources measured at the mouths of the selected tributaries.

The first problem was addressed by comparing unmeasured tributaries with measured tributaries under the assumption that tributaries with similar characteristics would have similar BAP. Tributaries were compared on the basis of extent and type of development, geology, water quality data, and studies in addition to that reported in (6) and other factors. As shown in Table 11 tributaries are ranked with Deep Creek which has a high percentage of dissolved phosphorus from municipal waste and cultural non-point sources compared with Brandts and Westbank Creeks which also have point source loadings. On the other hand, tributaries such as Shuttleworth and Trout Creeks which have most of their phosphorus in the particulate form due to erosion are grouped together with a lower percentage of BAP.

Tributaries were then grouped into respective lake sub-basins and the mean BAP determined (Table 12). The mean BAP for each lake sub-basin was calculated based on the sum of individual tributary BAP weighted on the basis of estimated phosphorus loadings. Individual tributary loadings were calculated from the total of known point sources and estimated non-point sources from (3) and estimated watershed source loadings based on the mean areal loading value from Table 8 and area of the tributary sub-basin.

TABLE 12

ESTIMATE OF BIOAVAILABLE PHOSPHORUS LOADINGS FROM WATERSHED SOURCES

Lake Sub-Basin	Percentage of Total Loadings as BAP*1		Ratio of Watershed Loadings to Total Loadings		Percentage of Watershed Source Loadings as BAP		Total Phosphorus Loadings from Watershed Sources*2 kg/yr		BAP Loadings from Watershed Sources*3 kg/yr
Wood	75	x	1.0	=	75	x	2,200	=	1,650
Kalamalka	55	x	0.8	=	44	x	5,100	=	2,200
Okanagan	61	x	0.7	=	43	x	63,400	=	27,300*4
Skaha	53	x	0.9	=	48	x	9,000	=	4,300
Osoyoos	50	x	1.0	=	50	x	14,800	=	7,400

*1 Percentage BAP for each lake sub-basin is based on the percentage of BAP calculated from the sum of total loadings and BAP loadings for individual tributary sub-basins. Direct drainage basins are not included in this calculation.

*2 Reference (3).

*3 Figures include loadings from forestry activities. As shown in Table 15 loadings due to forestry activities available for 1980 and projected for 1990 are subtracted from watershed sources for these periods.

*4 This figure differs from the figure for watershed sources set out in Table 15 due to the method of calculating loadings for the three basins of Okanagan Lake.

4. Projection of Phosphorus Loading to 1990

Projection of loadings to 1990 were made for all controllable sources as set out in Table 15. Non-point sources are projected to increase on the basis of population growth and growth of agricultural activities as set out in Appendix "B". Loadings from logging are not expected to increase since the Annual Allowable Cut for the Okanagan Timber Supply Area will likely remain about the same for the next 5-10 year period (13).

Loading from municipal sources in 1990 is uncertain since the method of treatment and level of phosphorus removal anticipated in the future is unclear. For example, City of Vernon effluent which is currently spray-irrigated may in the future be treated to remove phosphorus and discharged to Okanagan Lake, or some combination of treatment methods. As well as uncertainty regarding treatment methods and effluent loads there is also uncertainty in forecasting growth in volume of effluent discharged due to the possible sewering of additional areas. Increased collection of sewage from residential areas near Kelowna and Penticton would increase loading from municipal sources in excess of that predicted by population growth above.

As a first approximation loading from municipal sources is projected to increase on the basis of population growth alone under the assumption that the recommended objective of 90% phosphorus will be implemented as a minimum. This is currently the level of removal of phosphorus at the Penticton

Plant. Land disposal of effluent, if implemented, would likely achieve greater than 90% removal. The following table outlines loadings forecast for 1990 based on 90% removal of projected influent phosphorus loadings. Influent loadings from monitoring conducted in 1976-77 (7) were increased to 1990 levels based on projected population growth during this period.

TABLE 13

PROJECTED PHOSPHORUS LOADING TO 1990 FROM MUNICIPAL SOURCES
ASSUMING 90% PHOSPHORUS REMOVAL

Municipalities	Influent Loading (1976-77)*1 kg/yr	Population*2 increase from 1976 to 1991	Projected 1990 Influent Loadings kg/yr	Estimated Effluent Loadings assuming 90% Phosphorus Removal
Armstrong	1,600	73%	2,770	277
Vernon	26,700	73%	46,200	4,620
Kelowna	18,400	72%	31,650	3,165
Penticton	22,800	61%	36,700	3,670
Oliver	1,800	45%	2,610	260

*1 Reference (7).
*2 Reference (14).

Loadings for centers that were not included in the 1976-77 study were estimated based on the sewered population in 1981 and estimated per capita phosphorus loading of 1.5 kg. As set out in Table 14 loading projections to 1990 were made based on population growth between 1981 and 1991.

TABLE 14

PROJECTED PHOSPHORUS LOADINGS TO 1990 FROM WESTBANK,
OKANAGAN FALLS AND OSOYOOS ASSUMING 90% PHOSPHORUS REMOVAL

Municipalities	Estimated Influent Load for 1981 *1 (kg/yr)	Population Increase*2 from 1981 to 1991	Projected 1990 Influent Loadings (kg/yr)	Estimated Effluent Loading assuming 90% Removal
Westbank	2,220	40%	3,110	310
Okanagan Falls	1,440	28%	1,840	180
Osoyoos	3,750	35%	5,060	510

*1 Influent loads calculated on the basis of total sewered population (from municipal officials) and estimated annual per capita loading of 1.5 kg.

*2 (14)

Loadings from the Brandt's Creek Trade Waste Treatment Plant and the Summerland Hatchery which represent the only point source discharge of industrial effluents are projected to increase only slightly. Loadings from the Trade Waste Treatment Plant which includes mainly fruit processing waste are expected to increase by an annual growth rate of 2% which reflects anticipated market demand. Loading from the hatchery is expected to remain constant for the foreseeable future. Projected loading from non-point industrial sources are included under the "other sources" column in Appendix "B". The data base for most of these industrial sources did not permit projections to be made other than at this generalized level.

Loading from dustfall and precipitation, watershed sources and mainstem are shown as not changing in Table 15. This is largely because of a lack of background data to forecast changes rather than anticipation that these sources would remain constant. For example, mainstem loading may change in response to changes in total loadings to upstream lakes through control of sources or increased development.

5. CRITICAL REVIEW OF LOADING ESTIMATES

Estimates of loadings from non-point sources are approximate since they are subject to a considerable amount of uncertainty. For example, estimates of loadings from cultural non-point sources such as agriculture are affected by year to year changes in hydrology, as well as the basic uncertainty of the actual loadings to receiving water. Estimates for watershed sources and logging are even more uncertain due to the variability inherent in extrapolating results from selected watersheds based on limited sampling to the entire Okanagan Basin. A discussion of sources of variability concerning these loading estimates with implications regarding the use of the estimates is set out in Appendix "A".

It is recommended that future efforts to improve the estimates focus on those sources that can be feasibly controlled such as agriculture, septic tanks and logging to priorize sources and locations for controlling nutrients. For example, more detailed inventory data regarding locations and waste handling practices for septic tanks and livestock would increase the value of the estimates for management control purposes. As well, more site specific and intensive monitoring is recommended to demonstrate changes in water quality following management control of sources. Such monitoring will likely lead to improvements in the ability to predict loadings over time.

TABLE 15

COMPARISON OF PAST, PRESENT AND PROJECTED BIOAVAILABLE PHOSPHORUS LOADINGS TO THE OKANAGAN MAIN VALLEY LAKES

SOURCE	LAKE BASIN - kilograms per year														
	OSOYOOS			SKAHA			OKANAGAN			KALAMALKA			WOOD		
	1970	1980	1990	1970	1980	1990	1970	1980	1990	1970	1980	1990	1970	1980	1990
CONTROLLABLE[1]															
Point Source															
Municipal[4]	2,700	900	260	13,100	2,400	3,700	37,500	17,000	8,500						
Storm Sewer				30	35	50	280	475	680						
Industrial	90			60			720	1,050	1,200						
Non-Point Source															
Agriculture:															
Animals	300	520	550	480	430	460	2,180	8,800	8,900	300	670	700	410	520	530
Fertilizer	370	510	520	neg.	neg.	neg.	280	370	390	neg.	neg.	neg.	70	70	75
Septic Tanks	2,800	2,030	2,500	590	1,800	2,300	3,770	6,600	8,300	390	330	440	370	800	1,800
Logging	n/a	870	870	n/a	870	870	n/a	6,000	6,000	n/a	100	100	n/a	450	450
Other Sources	80	110	120	40	20	20	240	1,250	300	neg.	10	20	120	70	80
SUB-TOTAL	6,340	4,940	4,820	14,300	5.555	7,400	44,970	41,545	34,270	690	1,110	1,260	970	1,910	2,935
NON-CONTROLLABLE[5]															
Dustfall & Precipitation[2]	450	450	450	750	750	750	8,900	8,900	8,900	300	300	300	100	100	100
Watershed Sources[3]	7,100	6,200	6,200	4,200	3,300	3,300	24,500	18,500	18,500	2,200	2,100	2,100	1,650	1,200	1,200
Mainstem Loadings[3]	8,900	8,900	8,900	3,100	3,100	3,100	140	140	140	340	340	340			
SUB-TOTAL	16,450	15,550	15,550	8,050	7,150	7,150	33,540	27,540	27,540	2,840	2,740	2,740	1,750	1,300	1,300
TOTAL LOADING (rounded to nearest hundred)	22,800	20,500	20,400	22,400	12,700	14,600	78,500	69,100	61,800	3,500	3,900	4,000	2,700	3,200	4,200

1. Assumes that all controllable sources of phosphorus are biologically available.

2. Assumes that dustfall and precipitation sources are biologically available.

3. Biologically available loadings from watershed and mainstem sources were calculated as set out in (74). Loadings from logging is subtracted from watershed sources for 1980 and 1990.

4. Future loadings from municipal sources are uncertain due to type of treatment to be employed and the possibility of sewering additional areas in addition to the growth for areas already sewered. Future loadings are estimated on the basis of population growth assuming that as a minimum objective 90% of the phosphorus will be removed.

5. Loadings from non-controllable sources are shown to be the same for all years since the data base was not sufficient to separate differences between present and previous loadings, nor to allow projections. However, changes in loadings to lakes may result in changes in loadings to downstream mainstem lakes.

APPENDIX "A"

NON-POINT SOURCE LOADING UPDATE:
LIMITATIONS OF LOADING ESTIMATES

as prepared by
The Non-Point Source Loading Advisory Group

The Advisory Group generally felt that the core method of updating the non-point source nutrient loading component, hereafter referred to as the accounting method, was the most practical method to update loadings given the limitations of time and resources. The method permitted the comparison of current loadings with earlier loadings derived from the Okanagan Basin Study, as well as providing potential nutrient loadings from sources which is useful for management control programs. Notwithstanding the above statement, there are concerns expressed by the Advisory Group regarding the estimates generated using this method, particularly in terms of the static nature of the method, its coarseness and the applicability of the data for management purposes.

The most serious deficiency of the method in terms of its ability to predict nutrient loadings is that it does not consider time as a factor. It assumes a steady state and does not address seasonal or annual variation. The particularly important time variant factors such as runoff from surface water and groundwater are not considered. For example, time delays of leaching of nutrients through soil and groundwater from source systems are not included in the method. The consequences of employing an essentially static method of updating loadings is that loading estimates to the lakes may be in considerable error over the short term, particularly during non-average years.

Also, assumptions are made regarding the transmission of nutrients in surface and groundwater pathways to lakes which on a yearly basis are not realistic due to biological and chemical instream processes. Attenuation of nutrients obviously occurs within these pathways; however, in the accounting method it is assumed that nutrients entering a tributary suffer no losses to sediments or to the atmosphere. It is likely that a percentage of these nutrients associated with sediments, as well as nutrients taken up by the biota, will be flushed to the lake during infrequent periods of higher flows; however, this event-related loading increases the inter year variability and decreases the accuracy of the loading estimates on a yearly basis.

The second major deficiency in the update is due to the coarseness of the method of determining some source loadings with respect to boundary conditions such as soil, slope and depth to groundwater. Difficulties in obtaining locations of septic tanks installed since the Okanagan Basin Study necessitated the use of population data to estimate septic tank units. Septic tanks were assumed to have increased proportionally with population for actual locations determined in the Basin Study for 1970. However, due to the general level of the population data, i.e. lake sub-basin level, it was not possible to determine 1980 septic tank locations relative to boundary conditions; nor was it possible to determine the amount of fertilizer used for 1980 for most of the Okanagan.

Instead, fertilizer use was prorated from 1970 rates based on advice from District Horticulturists and comparison with the limited 1980 fertilizer inventory data. The net effect is that estimates of nutrient loadings from septic tanks and fertilizers are valid only for the same level of detail such as lake sub-basin level for septic tanks and both sources may not reflect actual loadings to receiving water due to spatial inconsistencies with regard to the boundary conditions. Boundary conditions as applied in the method are themselves general and do not address in a particular way sources located in sensitive areas that may produce greater nutrient loadings. For example, septic tanks located closer than 200 feet (61 m) from surface water or in poorly drained areas were included with others in the 0-500 feet (0-153 m) distance zone. Their greater contributions would, therefore, not be reflected.

As discussed, deficiencies in the method are apparent in following nutrients from sources through various pathways to receiving water. However, a major omission in the accounting method is the failure to include erosion as a source of nutrients. For example, overland transport of fertilizer and fertilizer associated with eroded soil is not included in the method. Although nutrient loadings due to erosion are implicit in the natural loadings component of the 1970 method, erosion apparently is considerably underestimated since 1970 monitoring to define these loadings was not flow weighted. As evidenced by 1980-81 monitoring in Shingle/Shatford Creeks particulate phosphorus loadings during freshet and storm events were significantly greater than estimates provided for in the accounting method for the entire year. Therefore, as part of the 1980 update, natural loadings were estimated using an average unit area load for the Okanagan based on tributary monitoring which covered a range of flow conditions. Also, since these loadings include nutrients from cultural sources such as livestock, as well as natural erosion, the name has been changed to "watershed sources".

During the present update an attempt was made to estimate the percentage of total loadings available for biological uptake. These biologically available phosphorus (BAP) and biologically available nitrogen (BAN) estimates constitute a first approximation of available loadings based on several major assumptions that remain largely untested. The composition of BAP and BAN is, for example, based on a limited data set from tributary and main valley stream monitoring that focused on the spring freshet. It is not known how representative the freshet period is to other periods of the year in terms of the composition of BAP and BAN. Also, an assumption was made, for example, that all of the dissolved phosphorus and fifty percent of the organic nitrogen were available. In fact, the actual availability of these fractions is uncertain. Finally, assumptions were made regarding the regeneration rate of phosphorus and nitrogen forms. All BAP and BAN were assumed to be immediately available; whereas, availability would actually occur over a period of time due to, for example, the gradual release of these nutrients from decomposition of organic material. In the case of a short residence time lake, such as Skaha, the assumptions regarding regeneration rate are particularly important since material may not remain in the lake long enough for complete regeneration of nutrients to occur. As indicated, the BAP and BAN estimates are preliminary and the accuracy of these estimates as with many elements of the update is uncertain.

In conclusion, although the loading estimates are the best that can be produced at this time, the limitations of the method will result in difficulties in predicting loadings to the lakes for individual years due to the absence of time variant factors such as runoff. Estimated loadings also may be in error due to the coarseness of the method and the omission of components such as erosion.

It is possible for management control purposes to use the potential loadings or gross loadings calculated for each source and drainage area based on the inventory update. However, it is accepted that movement of nutrients through soil and water pathways reduces the amount of nutrients reaching receiving water. The method does attempt to estimate this amount but the absolute values are subject to considerable uncertainty. Actual values occur within the range between potential loadings and estimated loadings to the main valley lakes. Further work on transmission coefficients and more dynamic routing of nutrients to receiving water is required to improve the estimated loadings.

APPENDIX "B"

WORKING PAPER, OKANAGAN BASIN IMPLEMENTATION PROGRAM DIFFUSE SOURCE LOADING PROJECTIONS

by R. McNeill,
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Diffuse sources of nutrients include agricultural animals and fertilizer, septic tanks, dustfall, permitted discharges, miscellaneous, and natural sources. Loadings from septic tanks, permitted discharges and miscellaneous sources are directly related to population, and increases are projected on the basis of population growth. Projections of loadings from agriculture and dustfall were made on the basis of expected growth in specific agricultural sectors. Information on these sectors was obtained from government and industry officials. No increases were projected for natural sources.

Agricultural

Continued increases in apple production are projected because of more intensive plantings. A two percent annual increase is projected. A 4% annual increase in grape production is forecast, with most occurring in the southern areas. In the northern areas, dairy production is expected to increase by about 2% annually, while beef production is expected to increase by 1% annually in the basin.

PERCENTAGE INCREASES IN AGRICULTURAL LOADINGS BY 1990

(% increase over 1980)

Sub-Basin	LIVESTOCK		HORTICULTURE		TOTAL	
	N	P	N	P	N	P
1	2.1%	2.8%	5.1%	5.1%	7.2%	7.9%
2	3.5	3.8	0	0	3.5	3.8
3	1.3	.7	1.5	2.9	2.8	3.6
4	1.0	1.6	4.2	2.5	5.2	4.1
5	0.5	1.8	5.0	8.5	5.5	4.3
6	6.8	8.0	1.0	0.0	7.8	8.0
7	5.6	7.8	2.0	0.1	7.6	7.9
8	3.7	4.3	5.1	2.4	8.0	6.7
9	1.8	4.0	4.6	3.4	6.4	7.4

Septic Tank Sources

The increase in nutrients is assumed to be proportional to the increase in population. The same pattern of septic tank versus waste collection systems is expected to occur in 1990 as in 1980.

PERCENTAGE INCREASE IN NUTRIENTS IN SEPTIC TANKS

Sub-Basin	N	P
1	22%	22%
2	35	35
3	23	23
4	32	32
5	11	11
6	28	28
7	28	28
8	28	28
9	12	12

Other Sources

These are primarily permit disposal and dustfall. Permit disposal is assumed to be directly correlated with population, while dustfall is correlated with irrigated acreage. Irrigated acreage is only expected to increase significantly in Sub-Basin 8; so all other sub-basins show no increase in nutrient loadings from dustfall. Miscellaneous sources are assumed to be directly related to population.

PERCENTAGE INCREASE IN NUTRIENTS DUE TO OTHER SOURCES

Sub-Basin	Permits and Miscellaneous		Dustfall		Total	
	N	P	N	P	N	P
1	70%	22%	0%	0%	70%	22%
2	20	29	0	0	20	29
3	22	23	0	0	22	23
4	17	16	0	0	17	16
5	3	7	0	0	3	7
6	17	14	0	0	17	14
7	15	25	0	0	15	25
8	2.9	2.8	8.1	8.2	11	11
9	2	5	0	0	2	5

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