CHAPTER 9

Establishment of Loading Criteria for the Okanagan Main Valley Lakes.

9.1 STANDARDS AND BENEFITS FOR THE CONTROL OF ALGAL AND OTHER AQUATIC PLANT GROWTH IN THE MAIN VALLEY LAKES

To provide a basis for projecting the effect of nutrient loadings on each of the main valley lakes over the next 50 years, the maximum desirable concentration of phosphorus in each lake at spring overturn has been related to lake water quality and annual phosphorus loadings. Thus, tentative standards are provided for the control of algal and aquatic plant growth in each of the main valley lakes.

9.2 ROLE OF NUTRIENTS IN BIOLOGICAL PRODUCTION

Photosynthetic plants require light and a number of elements for their maintenance and reproduction. The more important requirements are carbon (C), hydrogen (H), oxygen (0) and nitrogen (N), since these elements make up the predominant mass of cellular substance. Of most interest however, are the essential elements that limit plant (algal) growth when in short supply. Present and past studies indicate overwhelmingly that phosphorus (P) and nitrogen (N) are of particular importance in lakes. Phosphorus is considered to be the more easily controlled element in north temperate lakes, for the following reasons:

1. The element nitrogen accounts for approximately 75% of our atmosphere by weight, whereas the element phosphorus is a trace element accounting for less than .1% of the earth's composition. The control of the element nitrogen would therefore appear to be far more difficult than the control of trace elements such as phosphorus.
2. Certain bacteria and algae are capable of obtaining their nitrogen requirements directly from the atmosphere by the process of nitrogen fixation. Limiting nitrogen therefore, would not control the growth of these organisms. Nitrogen fixing algae are one of the main types which have produced nuisance blooms in the Okanagan lakes.
3. Nitrogen is considered a transient element which travels readily through a soil column to groundwater and eventually to surface waters. Conversely, phosphorus is readily bonded into a soil column and leaching or movement of this element occurs only when the amount of phosphorus exceeds the bonding capability of the soil.
4. Invasion of atmospheric nitrogen is constantly occurring in lakes at the air-water interface.

While the control of phosphorus is currently considered to be the most feasible method of controlling biological productivity in a lake, other elements and compounds may still cause specific problems if amounts exceed certain levels. Mercury and the pesticide DDT are two materials which have adversely affected certain Okanagan lakes. Mercury levels in fish, particularly trout, have reached levels in Kalamalka and Okanagan Lakes which are affecting the reproductive capability of this species. High DDT levels have apparently been detrimental to certain animal communities within a lake, while allowing other less desirable species to flourish. The effect of all elements must therefore be considered in assessing the condition of a lake as well as the overall biological productivity that the control of phosphorus may provide.

9.3 PHOSPHORUS FORMS AND BUDGETS

Phosphorus compounds in water are normally classified on the basis of separation techniques. Data reported in these investigations are presented as "orthophosphates" ($P0_4$) and "total phosphorus (TP). Total phosphorus is a measure of all the phosphorus in the water whether in a soluble form or contained in plant and animal cellular matter (insoluble). Orthophosphorus is that portion of total phosphorus which is in a soluble form and immediately available to plant life for synthesis (Table 9.1). While it would have been desirable to use orthophorphorus to establish criteria for acceptable lake loadings, this was not possible because of the following factors:

1. In lakes, orthophosphorus is in a perpetual state of flux, with release or uptake occurring in minutes, and hence it is difficult to know what percentage of the available Orthophosphorus one is measuring at any given time.
2. The concentrations of phosphorus required for optimum growth vary with species and environmental conditions. In lakes, optimum growth may occur at levels below 0.01 milligrams per liter. This figure corresponds closely to the limit of available analytical procedures used in this study to measure phosphorus. In most instances, values of orthophosphorus in the lakes and streams discharging into the Okanagan lakes were below this level of sensitivity. Total phosphorus has therefore been used as an indicator of the biological productivity of each lake, and has been used to establish loading criteria which may achieve, within limits, an optimum level of biological production for multiple water use.

In some of the lakes there is presently an overabundance of phosphorus (Chapter 7.1, 8) and other nutrients such as nitrogen are actually limiting biological production. In these cases however, phosphorus is still considered the key element and measures must be taken to reduce the supply of phosphorus to these lakes to levels where it again exerts a controlling influence on plant (algal) growth.

TABLE 9.1

FORMS OF PHOSPHORUS PRESENT IN SURFACE AND WASTEWATERS

DISSOLVED PHOSPHORUS		PHOSPHORUS IN SUSPENSION	
Ortho-phosphate (PO_4)	As organic colloids and/or combined with an adsorptive colloid	As mineral particles (e.g. apatite) and/or adsorbed on inorganic complexes such as $Fe(OH_3)$	Organisms Adsorbed on detritus and/or present in organic compounds
Dissolved Inorganic Phosphorus			
← Total Phosphorus in Filtrate →			
← TOTAL Phosphorus Content of Unfiltered Water →			

9.4 CRITERIA FOR PHOSPHORUS LOADINGS

The 'assimilative capacity' of a lake may be defined as the percent of total energy intake required for the growth, respiration and reproduction of plant life. This relationship may be expressed as:

$$\text{Assimilative Capacity} = \frac{\text{Nutrients required for plant growth, respiration and reproduction}/t}{\text{Total Nutrient Input}/t}$$

Where t = times in years.

For each nutrient, trace element and organic factor required for plant growth, there is a relationship between supply and demand that can be expressed by the assimilative capacity. In oligotrophic lakes, the nutrient supply is so low that the input limits plant populations and seasonal growth is balance by loss. In these cases, the input is equal to the amount required to sustain existing plant life and the assimilative capacity approaches 1. In eutrophic lakes, supplies of must nutrients are in excess of demand and values of the assimilative capacity are less than 1. In these cases, factors such as available light, competition or predation often limit growth to a greater extent than available nutrient supply. Wood Lake is an excellent example of this condition, where phosphorus is super-abundant and other nutrients, or the above mentioned controls, regulate plant populations before the external supply is exhausted. Unfortunately this type of control is not imposed until nuisance levels of algal blooms and weed growth have been reached.

By limiting annual loadings of phosphorus to a lake to that which can be assimilated within an acceptable level of biological production, high water quality can be maintained and future quality predicted, based on annual loadings. This approach has been used in establishing acceptable loading objectives for each of the main valley lakes. Since each lake will respond differently to a given nutrient load because of differences in mean depth, water renewal rates and other factors, these loading objectives will vary from lake to lake.

Values were set so as to achieve, within limits, an optimum level of biological production for multiple water use without the occurrence of nuisance algal blooms and extensive aquatic plant growth (Figure 9.1). These objectives apply primarily to macro-sources of nutrients and the lake as a whole, rather than to localized micro-sources of nutrients.

The values selected were based on information gained over the period 1969 to 1972, including the following:

1. Current average load of total phosphorus to each lake.
2. Present mean concentration of total phosphorus and orthophosphorus at spring overturn.
3. The sediment retention of phosphorus and internal loading where applicable.
4. Average algal biomass based on chlorophyll-*a.* determinations
5. Average biomass of zoobenthos and Zooplankton in relation to 1 and 4 above.

The present (1970) average concentrations of phosphorus at spring overturn, and suggested objectives for multiple water use are shown in Table 9.2. The rationale for establishing specific objectives for each of the main valley lakes is summarized below:

9.4.1 Okanagan Lake

Because certain areas of this lake exhibit eutrophic characteristics while the main body of the lake is oligotrophic, Okanagan Lake has been considered as three separate basins and loading objectives computed for each section. It should be recognized that this separation is not based on the natural state, but was introduced to facilitate water quality evaluations for this lake.

(a) North Basin

Loading objectives for this basin were set at 55,000 to 75,000 pounds of phosphorus per year. These loadings were considered to be approximately equal to the assimilative capacity of existing plant biomass in the central portion of the basin, which still exhibits excellent water quality. A loading of 66,000 pounds per year should be considered the maximum, recognizing that in any given year the load may reach 75,000 pounds due to uncontrollable sources of phosphorus. These values apply to the entire north basin and should not be confused with point source loadings to small regions which may exhibit local effects of nutrient enrichment. The shallow North and Vernon Arms will continue to exhibit some aquatic

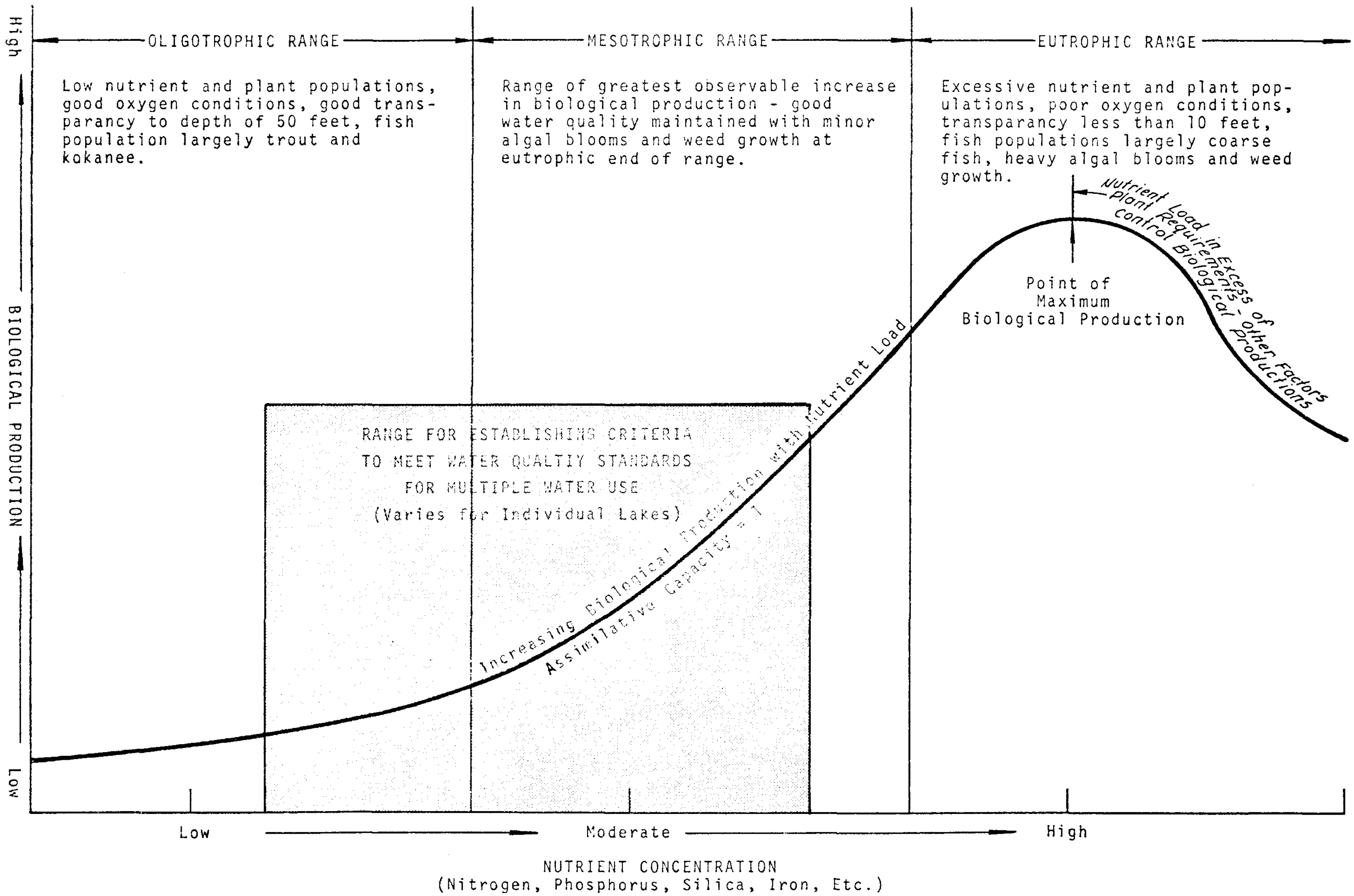

Figure 9.1

SCHEMATIC DRAWING OF RELATIONSHIP BETWEEN NUTRIENT LOADINGS AND BIOLOGICAL PRODUCTION, AND RANGE FOR SELECTING LOADING CRITERIA FOR MAIN VALLEY LAKES.

TABLE 9.2

TOTAL PHOSPHORUS CONCENTRATIONS AND LOADING CRITERIA - MAIN VALLEY LAKES

LAKE	AVERAGE CONCENTRATION OF TOTAL PHOSPHORUS AT SPRING OVERTURN 1971 MICROGRAMS PER LITER		MAXIMUM DESIRABLE CONCENTRATION OF PHOSPHORUS AT SPRING OVERTURN FOR MULTIPLE WATER USE QUALITY STANDARDS MICROGRAMS PER LITER		LOADING CRITERIA TO ACHIEVE DESIRABLE CONCENTRATIONS OF TOTAL PHOSPHORUS EQUALS (ASSIMILATIVE CAPACITY)	TROPHIC CHARACTER BASED ON NEW LOADING CRITERIA
	Average	Range	Average	Range	Pounds per year	
Wood Lake	104	83-125	20	10-30	2,000 - 3,000	Meso-Eutrophic
Kalamalka Lake	8	4-12	5	1-10	6,600 - 8,800	Oligotrophic
Okanagan Lake (as a Unit)	7	2-12	5	1-10	135,000 - 185,000	Oligotrophic
-North Basin	-	-	-	-	55,000 - 75,000	"
-Central Basin	-	-	-	-	55,000 - 75,000	"
-South Basin	-	-	-	-	25,000 - 35,000	"
Skaha Lake	24	15-32	12	10-15	30,000 - 40,000	Mesotrophic
Vaseux Lake					17,500 - 22,000	Eutrophic
Osoyoos Lake	12	10-15	10	5-15	26,000 - 37,000	"

plant growth due to basin characteristics and continuing diffuse loadings from the Armstrong and Vernon areas respectively.

(b) Central Basin

Objectives for the central basin are the same as for the north basin and the same comments apply. Localized problems are expected to continue along the Kelowna foreshore.

(c) South Basin

Values for this basin have been set lower than the previous two basins so that this relatively large section of Okanagan Lake can act as a buffer for lakes below. Positive point sources are few in this section of the lake and the very large volume of excellent quality water should protect Penticton beaches from any nuisance aquatic plant growths and insure a low nutrient discharge from Okanagan Lake to Skaha Lake. Any proposed point sources should be kept out of this basin to maintain a sizeable reservoir of good quality water between Kelowna and the lake outlet at Penticton. A loading of 35,000 pounds per year should be considered an absolute maximum, again recognizing that values below this will further ensure the maintenance of good water quality.

9.4.2 Skaha Lake

Proposed criteria of phosphorus loadings to Skaha Lake range from 30,000 to 40,000 pounds per year. These somewhat high values take into account the very short retention time of water in this lake (one year) and the excellent source of good quality water flowing into the lake from Okanagan Lake.

If values remain within these established limits, good water quality should be achieved. Sporadic algal blooms may continue to occur along with moderate aquatic plant growth on the eastern shoreline, however the annual occurrence of heavy blue-green blooms should be eliminated.

9.4.3 Osoyoos Lake

Phosphorus loading criteria established for this lake range from 26,000 to 37,000 pounds per year. These values allow for the very rapid water renewal rate (residence time) which prevents the accumulation of large amounts of nutrients. The maintenance of phosphorus loads below 37,000 pounds per year should prevent extensive algal blooms and control aquatic plant growth to within manageable limits. Osoyoos Lake is largely dependent on the quality of water in Skaha Lake and in Okanagan River, and improvement in the quality of these lake and river waters will also benefit Osoyoos Lake.

9.4.4 Kalamalka Lake

Loading objectives for Kalamalka Lake range from 6,600 to 8,800 pounds per year. This is much lower than for the other lakes because of the small volume of inflow and the long retention time of water in this lake. Its calcium carbonate cycle may partially buffer it from nutrient overload, but any large increase in phosphorus loadings may cause this carbonate system to collapse. The lake is already an effective plankton producer as evidenced in bioassay studies, and recent paleolimnological investigations. If phosphorus loadings can be curtailed to within these proposed limits, the lake should maintain its present excellent condition.

9.4.5 Wood Lake

The loading objectives set for Wood Lake are 2,000 to 3,000 pounds of phosphorus per year. These annual rates are no doubt above historical, but below present levels. If the objectives are met and a continual source of good quality water reaches this lake, the occurrence of annual blue-green algal problems should be eliminated as well as the need for periodic aquatic plant harvest. The lake will continue to be a productive lake, but not in the sense of objectionable nuisance organisms. Clarity and oxygen levels will be improved and sport fisheries rejuvenated if these objectives are met. Because of the existing high internal loading of phosphorus to this lake, a significant decrease in phosphorus loadings will be required initially to affect any change in its condition. The lower loading objective of 2,000 pounds should therefore be used until a significant improvement in the water quality of Wood Lake has been achieved.

The higher inflows and reduced retention time of water in this lake due to industrial cooling water discharges, should speed the recovery of the lake, but will have no immediate effect on its water quality.

9.4.6 Vaseux Lake

Proposed objectives for this lake range between 17,500 and 22,000 pounds of phosphorus per year. The achievement of these objectives depends primarily on improving the quality of Skaha Lake and Okanagan River water. Extensive aquatic plant growth will always be an integral part of this lake due to its shallowness and rich bottom sediments. This habitat is considered suitable for this lake as it has been established as a wildlife sanctuary.

9.5 COSTS AND BENEFITS ASSOCIATED WITH LAKE MATER QUALITY

The costs associated with lake water quality maintenance and/or improvement involve the expenses incurred with the construction of waste treatment facilities which reduce nutrient contributions. These costs are dealt with at length in Technical Supplement VI.

The benefits of water quality involve evaluation of many social and economic values; i.e. beach recreation, aesthetics, beach oriented tourist expenditures. These benefits are explained and evaluated in relation to water quality control in Technical Supplement VIII.