Province of British Columbia
Ministry of Environment
ASSESSMENT AND PLANNING DIVISION

WATER QUALITY OF LAKE MAXWELL, SALTSPRING ISLAND

Working Report

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SUMMARY

Lake Maxwell on Saltspring Island was examined to determine its suitability as a bulk water supply system, both in terms of water quality and water quantity. The lake appears to be a supply of good quality water in reasonable quantities. The lake could presently yield an additional 130-300 dam^3 per year for water supply, depending on annual precipitation. With potential storage, a water yield of 240-340 dam^3/yr could be possible.

The lake, because of its small watershed (1.2 km^2) and relatively long water residence time (1.7 years on average) is susceptible to disturbance from the watershed. The lake presently has nutrient concentrations which are sufficiently high to warrant concern that further increases could cause future problems with algal growth.

Despite the occurrence of warm surface water temperatures and summer hypolimnetic oxygen depletion, the lake can presently serve as a source of good quality water, superior to any other source on the island.

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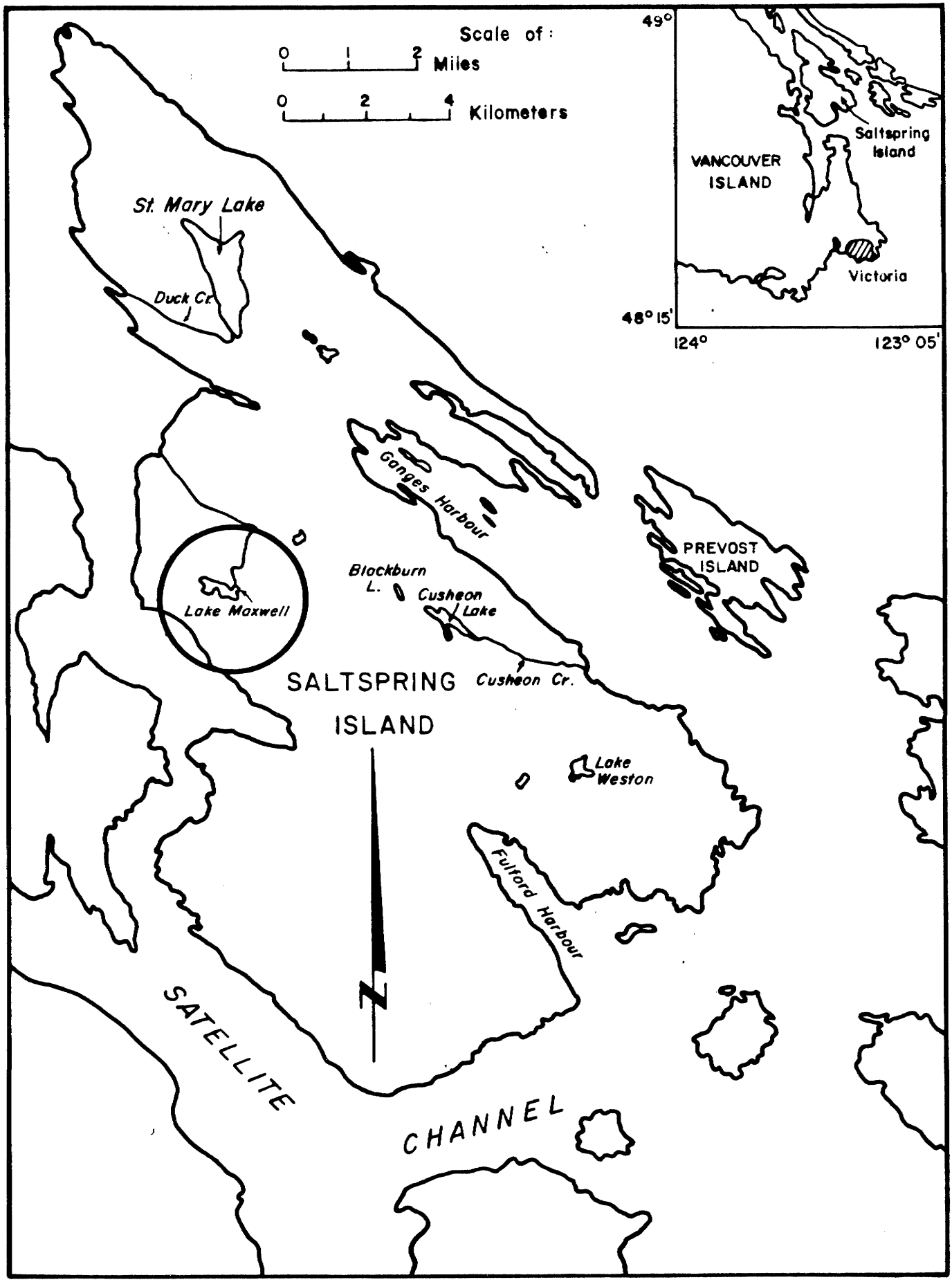


FIGURE 1: Location of Lake Maxwell, Saltspring Island

1. INTRODUCTION

Lake Maxwell is located on Mount Maxwell in the west central portion of Saltspring Island (Figure 1). The lake is part of the water supply to the North Saltspring Water Works (NSWW) District which serves a portion of the north end of the island. An application by NSWW for a water licence to withdraw additional volumes of water from the lake was made in 1980. The Regional Manager of the Water Management Branch requested information from the Aquatic Studies Branch in February 1981 on the water quality of the lake. Since very little information had been collected on Lake Maxwell, sampling was carried out during 1981 in order to provide adequate water quality information to respond to this request.

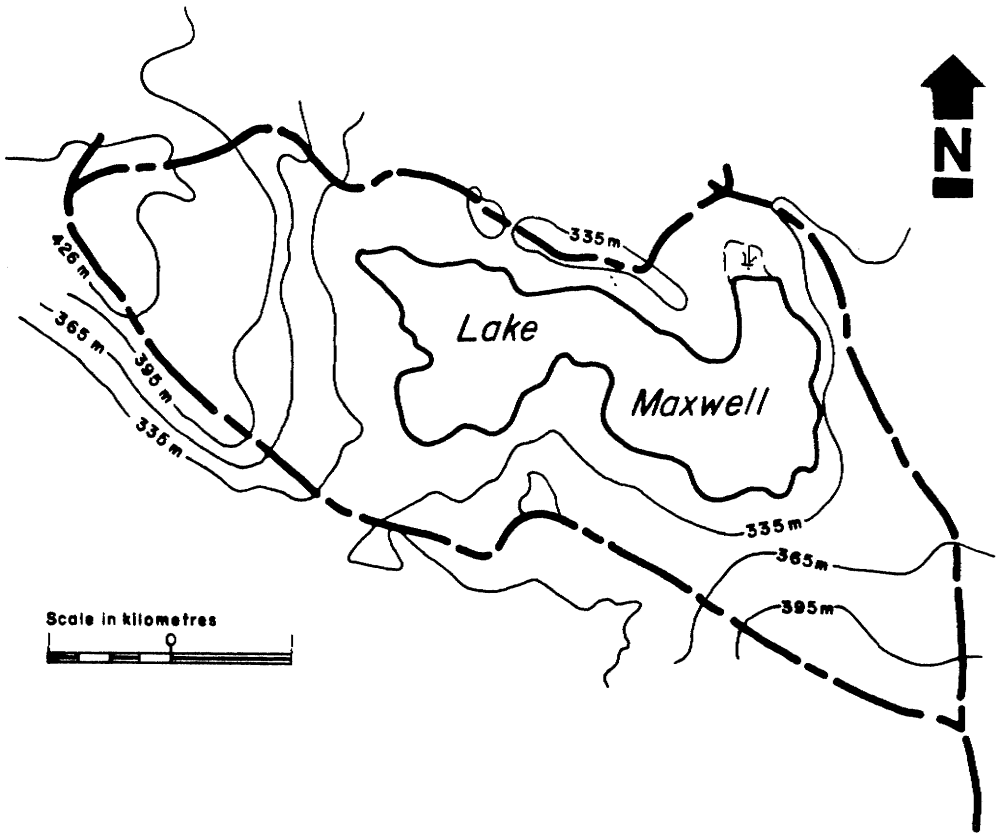


FIGURE 2: Watershed Boundary and Topography of Lake Maxwell

2. WATERSHED CHARACTERISTICS

The watershed boundary and surrounding topography are presented in Figure 2.

2.1 GEOLOGY AND SOILS

The general geologic area in which Lake Maxwell is located is the Nanaimo lowlands of the Georgia Depression (Holland, 1964). The surficial geology is sedimentary rocks with volcanic intrusions. The soils of Saltspring Island have been described by Day et al., (1959). A more recent soils survey has been completed in 1980 by Agriculture Canada (van Vleet, in prep.). An interim copy is shown in Figure 3.

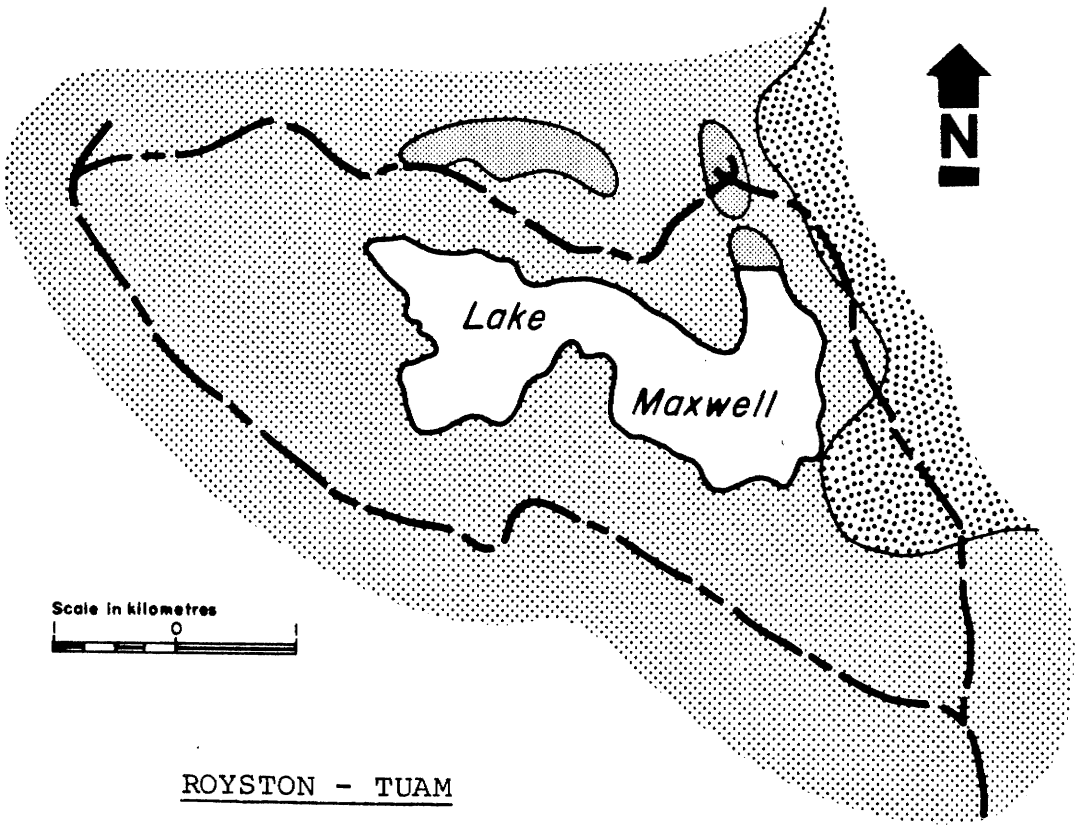
2.2 VEGETATION

The watershed contains a number of vegetation communities. In the immediate area around the lake is an association of Douglas-fir, red alder, grand fir with salal, and sword fern on deep till (some colluvium) (Hirvonen et al., 1974). Other major associations (Figure 4) are a Douglas-fir/salal/arbutus, Douglas-fir/western hemlock/red alder, and Douglas-fir/western red cedar/red alder.

The vegetation cover in the watershed is almost entirely forest, and as a consequence, disturbance resulting from settlement is relatively limited. The forest is second growth, largely immature Douglas-fir.

2.3 LAND USE

The land within the watershed is held in fairly large parcels (Figure 5). The Islands Trust presently has jurisdiction over land use and



ROYSTON - TUAM

These are usually upland soils developed on coarse textured mantles that are underlain by compact clay loam till. Topography may be undulating to steeply sloping.

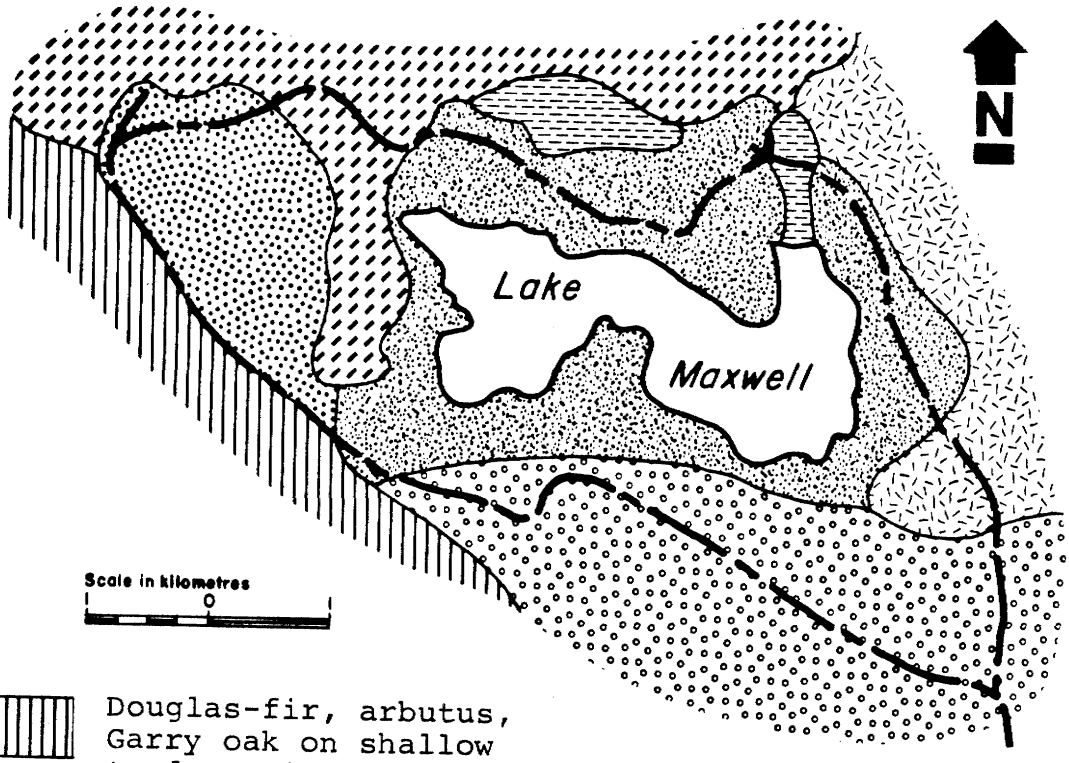
SATURNA

These soils are composed of gravelly and sandy veneer, 4.40 inches thick overlying sandstone. They occur on moderate to very steeply sloping landforms and include a significant proportion of bare rock.

ARROWSMITH - METCHOSIN

This association is composed of deep to moderately deep organic soils that are subject to frequent ponding or high water tables. They are respectively underlain by clays at depths of 60 to 18 inches.

FIGURE 3: Watershed Soils of Lake Maxwell



Douglas-fir, arbutus, Garry oak on shallow to deep till and culluvium.

Douglas-fir, western red cedar, red alder on deep till with minor rock inclusions.

Douglas-fir, red alder, grand fir on deep till.

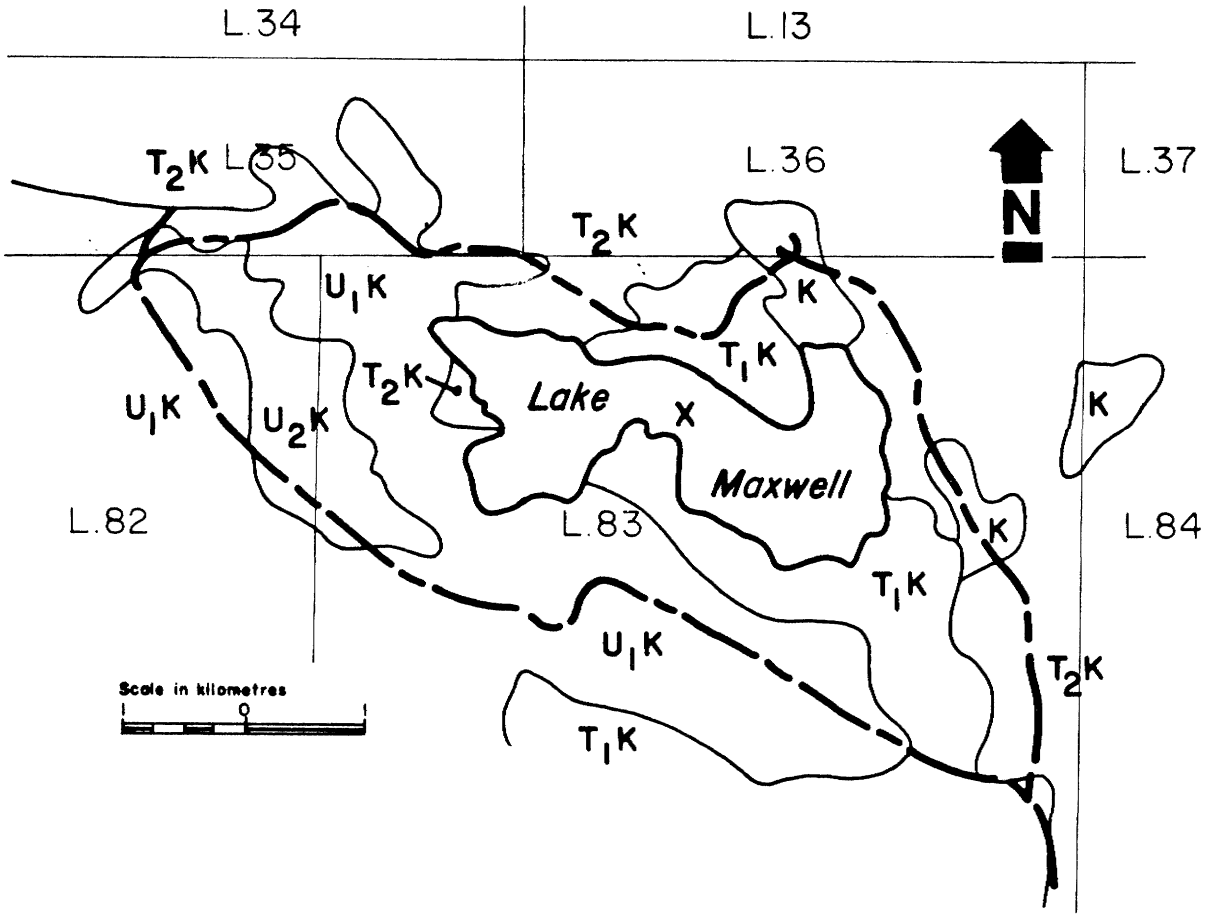
Swamp grass and associated vegetation on organics.

Douglas-fir grass moss on shallow soils over rock.

Douglas-fir, arbutus, salal on till over rock with deep till inclusions.

Douglas-fir, salal, arbutus on deep till with shallow to rock inclusions.

FIGURE 4: Vegetation Cover Within the Lake Maxwell Watershed



T_1 Mature Productive Woodland. Land bearing a productive forest type with at least one tree per acre greater than 11.1" d.b.h.

T_2 Immature Productive Woodland. Productive forest land with immature cover.

U_1 Non-productive Woodland on a Productive Site. Forest land which has been logged, burnt or diseased and has either not been satisfactorily restocked or has been restocked by a non-commercial type.

U_2 Non-Productive Woodland on a Non-Productive Site. Land bearing a non-productive type on a non-productive site.

K Open Woodland and Forest Range. These are classified as pasture and range if they are on, or continguous with, occupied farmland or if the evidence or knowledge of grazing activity. They are also given a woodland classification, e.g. T_2K

X Water Surfaces. Excluding temporarily flooded hay meadows, etc.

FIGURE 5: Land Use Within the Lake Maxwell Watershed

subdivision and has imposed a 12.1 hectare (30 acre) minimum lot size. Little development exists at present in the watershed (only one permanent residence), but additional residential development is possible. The North Saltspring Water Works owns 49 ha of the northern half of lot 83. This encompasses the majority of the lake's perimeter. Texada Logging Ltd. owns the south quarter of the northern half of lot 83, and MacMillan Bloedel Ltd., together with two private holdings are the remaining properties owners in lots 35 and 82.

2.4 CLIMATE

The most important climatic parameter for the aspects of Lake Maxwell watershed considered here is precipitation. A summary of precipitation data for the closest climate station and the pattern of estimated monthly watershed runoff are shown in Table 1, and illustrated in Figure 7. Because of the low precipitation and runoff during the summer, and limited potential live storage (355 dam^3) to catch for winter runoff, the supply of water during the summer is reduced.

TABLE 1. PRECIPITATION DATA FOR LAKE MAXWELL

Month	30 Year Average* (mm)	Estimated Net Inflow in an Average Precipitation Year** (dam^3)
January	177.3	181
February	112.3	124
March	91.4	66
April	54.9	9
May	36.8	-9
June	36.3	-16
July	21.6	-25
August	28.4	-20
September	41.7	-6
October	100.8	12
November	146.1	37
December	178.8	208
	Σ 1026.4	Σ 561***

* Saltspring Island Climate Station Location 48° 51' N; 123° 30' E; 78 m elevation; (1941-1970)

** Based on 3 years of local lake outflow and water level data and adjusted to long-term Water Survey of Canada stream flow station: Bings Creek near mouth (08HA016).

*** See Hydrology Section for the calculation of the annual watershed runoff.

3. LAKE CHARACTERISTICS

Lake Maxwell is at an elevation of 375 metres above mean sea level. The lake contains no surface water inflow streams and it appears that the lake is fed by overland flow and groundwater. The outlet stream drains toward the north and enters Sansum Narrows near Erskine Point.

The bathymetry of the lake was measured in May 1972 by the Fish and Wildlife Branch (Figure 6). Another survey was carried out by the Aquatic Studies Branch in 1981. The lake has two subsurface basins, has a surface area of 26 ha, and has a volume of 946 dam^3. The mean and maximum depths are 6.5 m and 17.9 m respectively. Approximately 45 percent of the lake surface is within the littoral zone (i.e. less than 6 m). The watershed area is approximately 1.2 km^2 and the lake comprises about 22 percent of the watershed area.

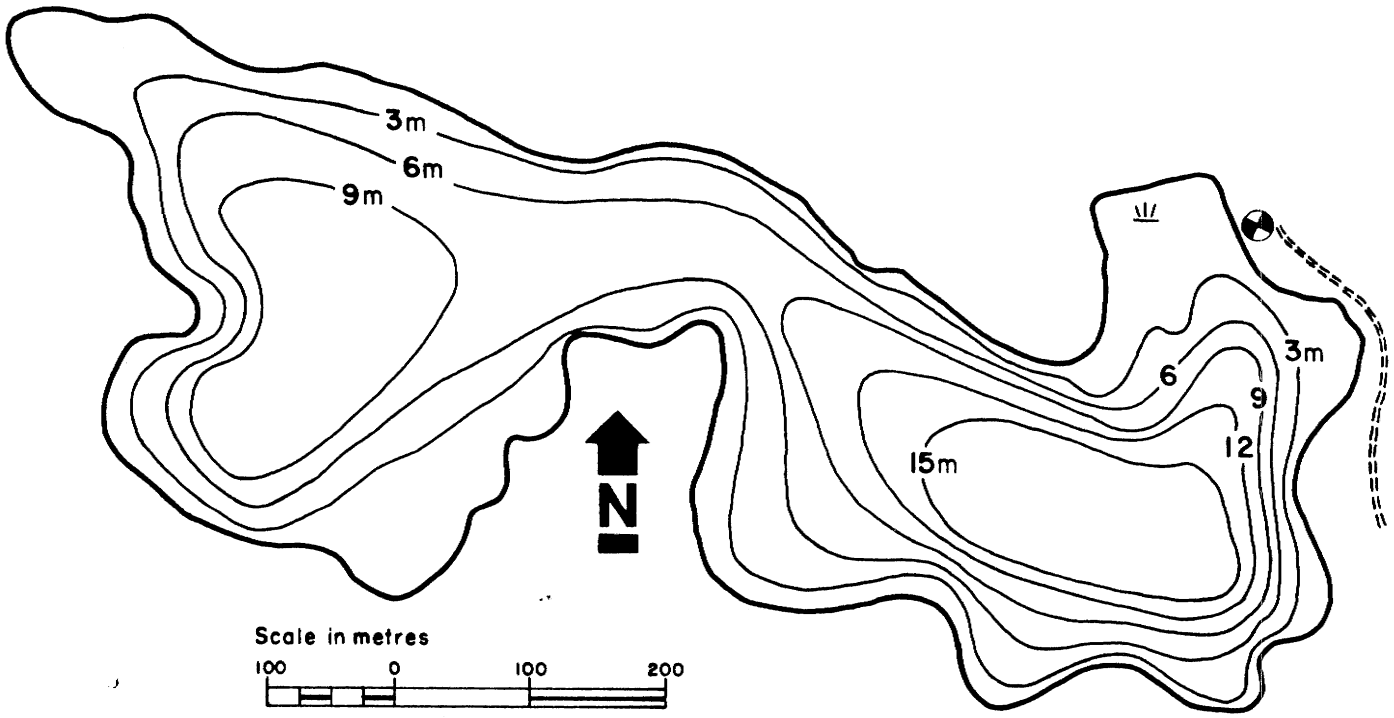


FIGURE 6: Bathymetry of Lake Maxwell

4. HYDROLOGY

The volume of inflow water was important for two reasons. The theoretical water residence time was important for water quality considerations, while the filling time of live storage was important for water yield considerations. The annual inflow to Lake Maxwell was calculated by the Surface Water Section, Water Management Branch (Coulson, 1982a) and is shown in Table 2.

TABLE 2. FREQUENCY ESTIMATES FOR ANNUAL RUNOFF INTO LAKE MAXWELL

Type of Runoff Year	Recurrence Interval (years)	Lake Inflow (dam^3)	Theoretical Water Residence Time (years)	Theoretical Filling Time of Live Storage (years)
Low	50	247	3.8	1.4
	20	297	3.2	1.2
	10	348	2.7	1.0
Mean	2	561	1.7	0.6
	10	780	1.2	0.5
	20	836	1.1	0.4
High	50	892	1.1	0.4

The table indicates that the average filling time of the live storage is 0.6 years. However, depending on the annual inflow, a range of filling rates can be encountered (1.4-0.4 years). The pattern of estimated monthly inflow in an average precipitation year is illustrated in Figure 7.

The safe reservoir yield was also calculated by the Surface Water Section of the Water Management Branch (Coulson, 1982b). This allowable supplementary demand is shown as Table 3. The information was determined for present and potential Lake Maxwell storage conditions for a number of

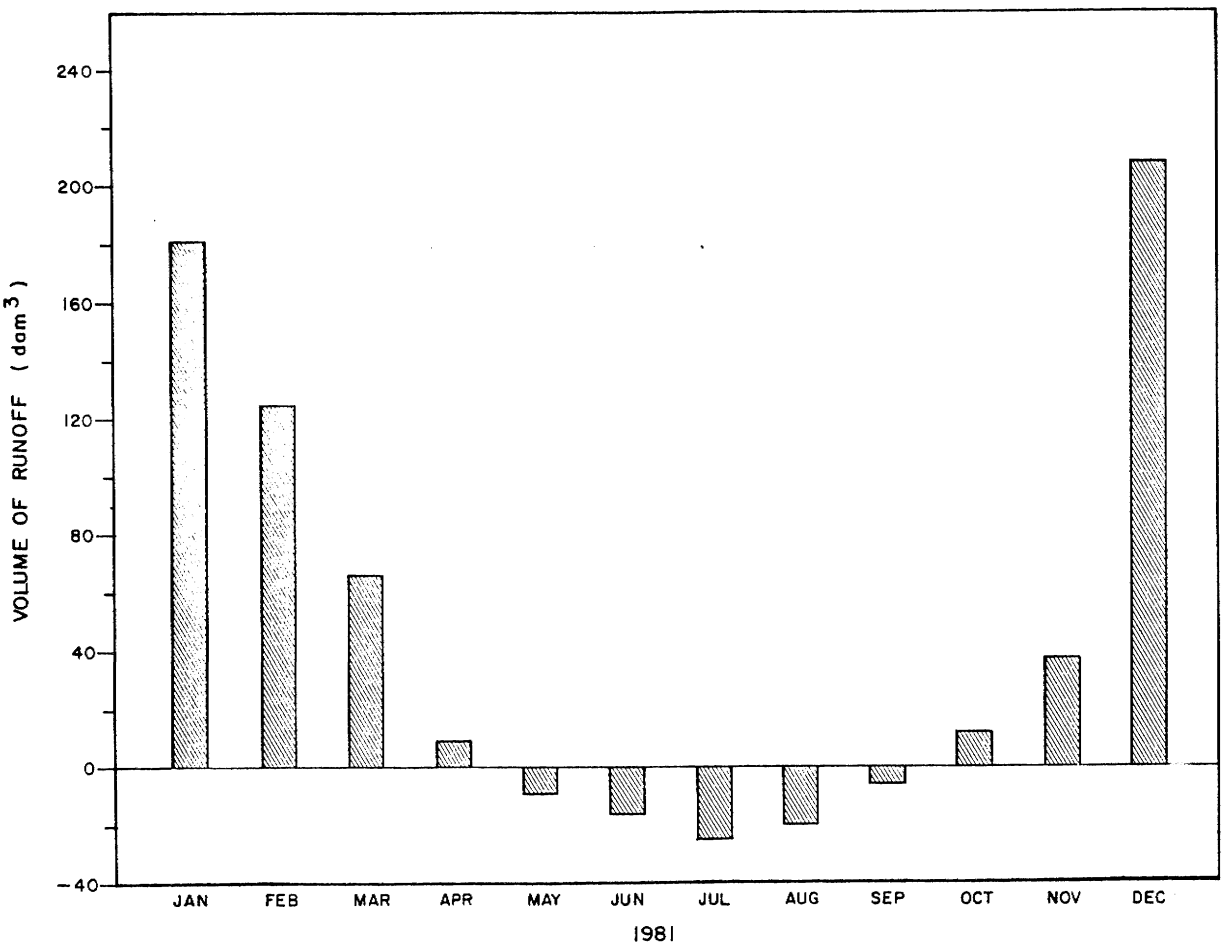


FIGURE 7: Estimated Mean Monthly Water Input To Lake Maxwell

drought conditions. This allowable demand is in addition to the current annual demand of 200 dam^3 (1979 and 1980 recorded diversion from Lake Maxwell).

Annual drought runoff estimates were based on three years of observed net inflow data (Coulson, 1982a), adjusted for observed lake evaporation (Saanichton, Agriculture Canada). The annual runoff estimates were distributed on a monthly basis using a water balance method which incorporated a long-term monthly precipitation and evaporation distribution for Saltspring

TABLE 3. ALLOWABLE SUPPLEMENTARY ANNUAL DOMESTIC DEMAND (dam^3)

Recurrence Interval Drought (years)	Present Storage (355 dam^3)	Potential Storage (530 dam^3)
1 in 50 years	130	240
1 in 20 years	160	270
1 in 10 years	190	300
1 in 2 years	300	340

The potential storage figures are based on the assumption that additional storage would be developed by construction of a dam at the lake outlet.

Island climatic station.

A monthly mass analysis computer program was used to estimate the following allowable supplementary domestic demands. In each case a single drought year was preceded and followed by two mean years.

5. WATER QUALITY

The water quality information for Lake Maxwell is limited. Some information was gathered in 1972 during the Fish and Wildlife Branch lake survey and by the Water Investigations Branch in 1973. The most notable aspect of these data was the dissolved oxygen profiles (Table 4). Additional water chemistry data were gathered largely by the Aquatic Studies Branch in 1981. The existing data indicate that Lake Maxwell has good water quality characterized by low biological productivity, good water clarity (Table 5), and low concentrations of most chemical constituents. The only exceptions to this general pattern were mid or late summer hypolimnetic concentrations of several parameters discussed below.

The physical stratification of the lake affects water quality and is of importance in determining optimum depth for water withdrawls particularly for drinking water supplies.

From the profile data, a time-depth diagram for temperature was constructed (Figure 8). The lake, if it does not freeze, would be expected to be isothermal throughout the period from November to March. In April, increasing air temperatures and solar warming initiate the stratification process. By July, a stable and well established thermocline separates the epilimnion (upper 5 m) and hypolimnion (below 10 m). By late summer, the surface begins to cool and the thermocline occupies a slightly deeper stratum. With cooler autumn temperatures, wind gradually destroys the stratification and returns the lake to winter isothermal conditions.

The dissolved oxygen vertical stratification is largely a function of the temperature stratification. Oxygen concentrations at or near saturation exist throughout the winter circulation period. If ice cover occurs, it would be expected that some depletion would take place under the ice. However, no measurements were made when ice covered the lake. The most important changes in oxygen take place during summer stratification. The pattern

TABLE 4. SUMMER DISSOLVED OXYGEN PROFILES FOR LAKE MAXWELL, 1972 AND 1973

Fish and Wildlife Branch - Lake Survey			Water Investigations Branch (Sampled by: Drs. Buchanan and Foweraker)		
May 11, 1972			August 28, 1973		
Depth (m)	Temperature (°C)	Dissolved Oxygen (mg/L)	Depth (m)	Temperature (°C)	Dissolved Oxygen (mg/L)
0	11.1	9.5	0	18.0	9.2
1	11.1		1	18.1	8.9
3	11.0		2	18.2	8.9
5	8.1	6.5	3	18.2	8.9
10	5.0		4	18.1	8.8
15	3.6	3.0	5	18.1	8.8
17	3.6		6	16.0	7.9
			7	12.4	6.8
			8	9.8	7.8
			9	7.7	6.0
			10	6.6	4.4
			11	6.0	3.4
			12	5.5	2.3
			13	5.1	0.5
			14	5.0	0.5

TABLE 5. WATER CLARITY MEASUREMENTS (SECCHI DEPTHS) FOR LAKE MAXWELL

11 May	1972	4.0 m
16 June	1981	3.5 m
18 Aug.	1981	4.3 m

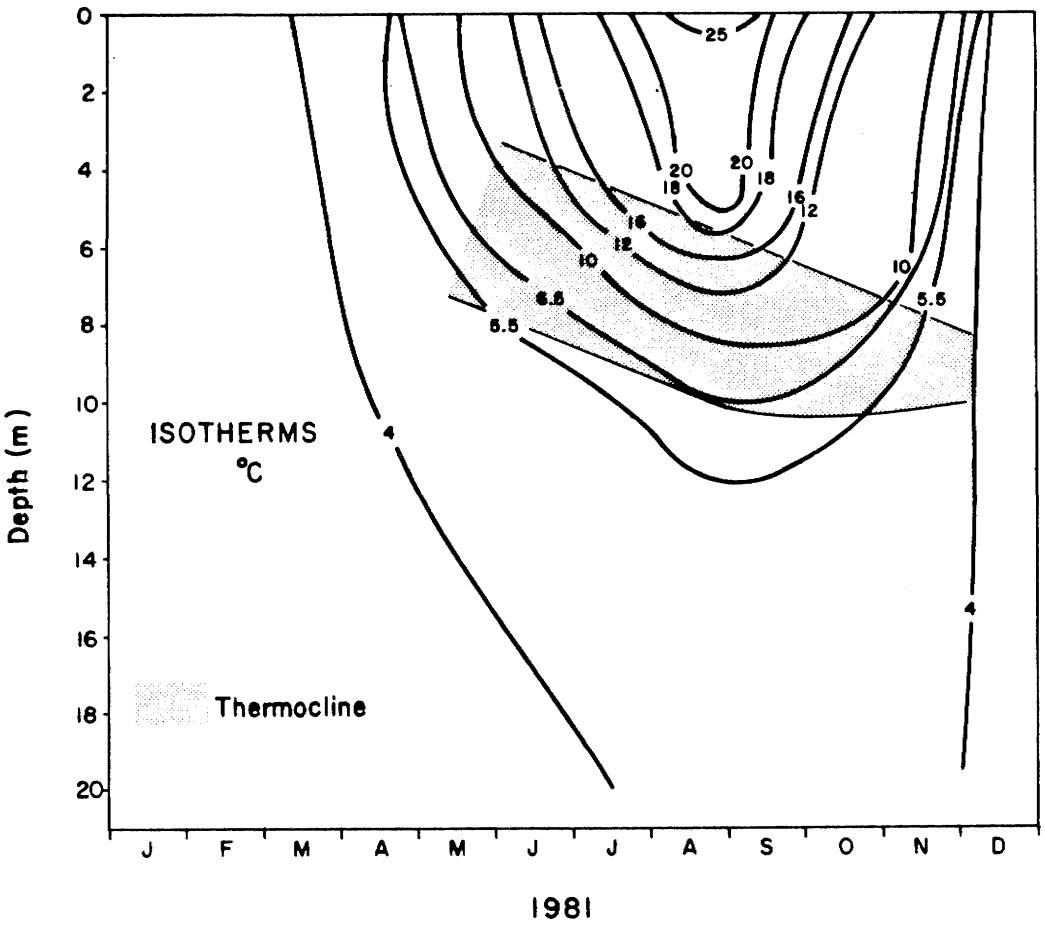


FIGURE 8: 1981 Time-Depth Diagram for Water Temperature

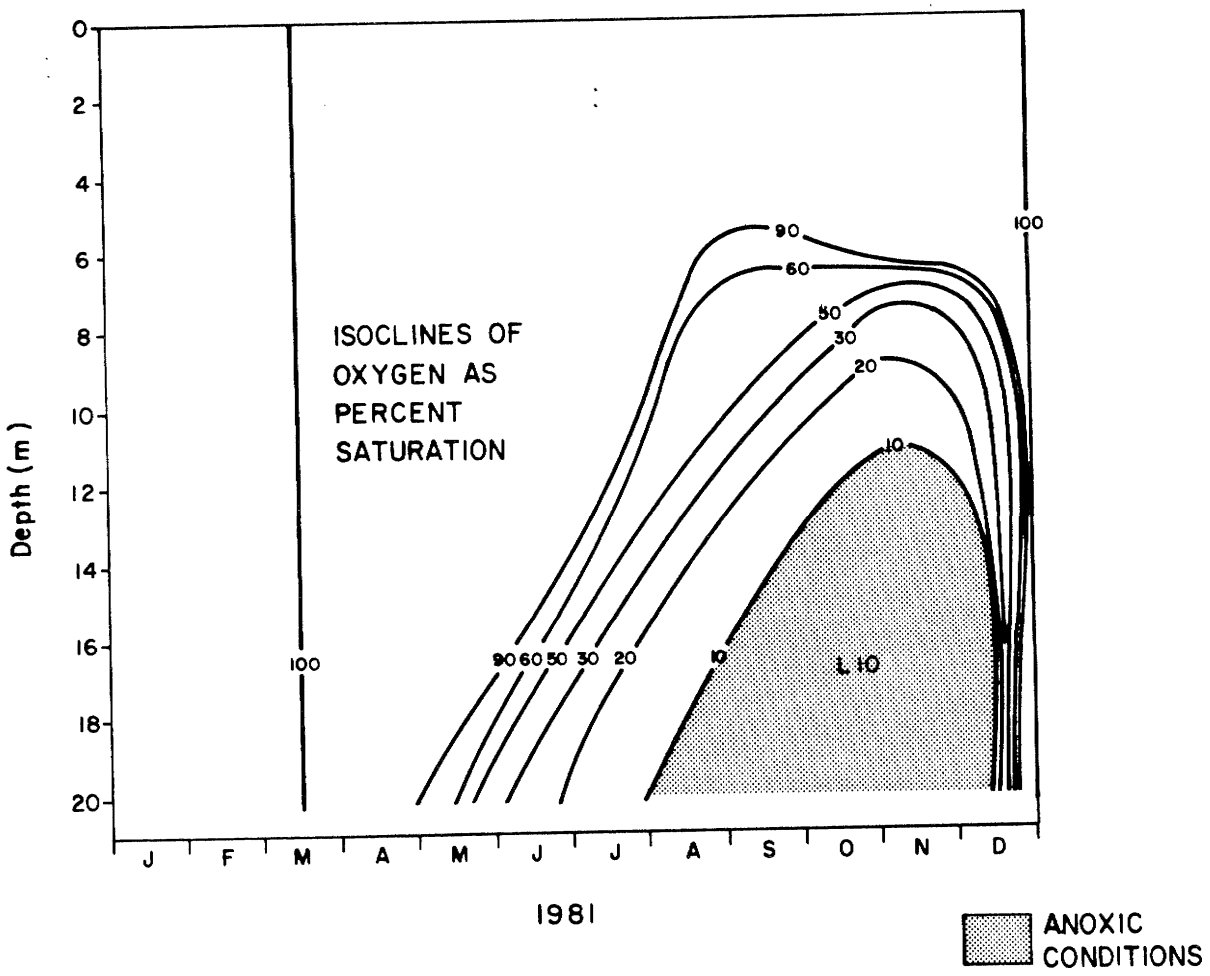


FIGURE 9: 1981 Time-Depth Diagram for Dissolved Oxygen

of concentrations over time and depth is shown in Figure 9. It indicates that in late summer, oxygen concentrations decrease to less than 10 percent saturation (>1 mg/L) at 15 m. By October, the anoxic zone extended from the bottom to 11 m.

The preferable location of an intake would be as deep as possible for temperature considerations (drinking water standard is 15°C, objective is <15°C), and to avoid any algal growth which might occur. This indicates that it would be desirable to draw from a depth below 7 metres. To meet the drinking water standard of 3 mg/L dissolved oxygen, any depth above 7 metres would be satisfactory, but should be preferably above 6 metres. Summer is the only period during which any unfavourable oxygen concentrations exist. The optimum intake depth during this period would be between 6 and 7 metres below the lake surface. Annual variation between years may cause differences in depth of stratification and minor modifications to the recommended depth may be required.

The water chemistry of the lake was evaluated for drinking water suitability using those criteria cited by the B.C. Ministry of Health (1969) and Health and Welfare Canada (1978). The measured parameters and the recommended standards are summarized in Table 6. A number of parameters are omitted from the table as no lake samples were analyzed for heavy metals, pesticides and complex organics. Because of the watershed's present land use, surficial geology, and vegetation, it would not be expected that the aforementioned constituents would be present in sufficient quantities in Lake Maxwell to cause any problems.

The parameters of more direct concern would be those associated with temperature, oxygen and algal growth. Certainly, water drawn from the surface in summer would not meet the objective for temperature, nor would water drawn from deep depths during the summer meet the objectives for dissolved oxygen, as discussed above. One area for which no quantitative standards

TABLE 6. SUMMARY OF WATER QUALITY PARAMETERS IN RELATION TO THE RECOMMENDED DRINKING WATER STANDARDS AND OBJECTIVES

Parameter	Objective	Standard	Lake Maxwell
nitrate (mg/L)	<0.001	10	surface $\leq$0.020 mg/L; maximum value at 10 m on 18/VIII/81 of 0.100 mg/L.
total alkalinity (mg/L)	300	500	14.8 - 17.1
ammonia-nitrogen (mg/L)	0.01	0.5	surface $\leq$ 0.006 mg/L; maximum value at 14 m on 18/VIII/81 of 0.072 mg/L.
calcium-total (mg/L)	<75	200	5.1 - 5.4
magnesium-total (mg/L)	<50	150	1.05 - 1.3
total phosphorus (mg/L)	<0.200	0.200	surface 0.007-0.016 mg/L; maximum value at 14 m on 18/VIII/81 of 0.031 mg/L.
total dissolved solids (mg/L)	<500	1000	36 - 40
total hardness (mg/L)	<120		17.1 - 18.2
sulphate-dissolved (mg/L)	<250	500	<5
true colour (T.C.U.)	<15	15	surface $\leq$5; maximum value at 10 m on 18/VIII/81 of 10 T.C.U.
pH		6.5-8.5	6.9 - 7.6
temperature (°C)	<15	15	see text

standards exist is algal growth. Related to this is the nutrient content of the water which usually correlates directly with the quantity of algal biomass present. Objectives and standards for drinking water nitrogen and phosphorus are set with regard to human health, not algal growth. The algal growth can seriously limit the usefulness of water by creating difficulties with filtration and problems of taste and odour.

As noted above, no quantitative criteria exist for concentrations of either algae or nutrients causing algal growth. The most commonly used measurement for algal biomass is chlorophyll a, and a reasonable concentration which could be used as an objective is a summer mean of less than 2 µg/L (an average of at least 6 monthly measurements). A corresponding concentration for phosphorus (the usual limiting nutrient) would be a spring overturn concentration of 10 µg/L. These values for chlorophyll and phosphorus correspond to the upper limit of the trophic level of oligotrophy (Rast and Lee, 1978; Carlson, 1977). In Lake Maxwell phosphorus is presently near the suggested 10 µg/L limit (9 µg/L, March 25, 1981, although this probably underestimates the spring overturn concentration). Insufficient chlorophyll a data are available for Lake Maxwell to make any definite comparison to the suggested objective noted above (2 µg/L), but it is expected to be near this value. Chlorophyll a was 2.3 µg/L from a sample in March, 1981 and 1.5 µg/L in June, 1981. In August, 1981 values of 0.5 µg/L or less were ensured at depths of 0 to 6 metres. These data indicate low algal biomass.

In relative terms the water of Lake Maxwell is of a much higher quality than that of St. Mary Lake which is also used as a bulk water supply. In St. Mary Lake, the overturn phosphorus concentration (1980) was 44 µg/L, or about three times the maximum concentration of total phosphorus in Lake Maxwell. The summer mean chlorophyll a in 1980 for St. Mary Lake was 8.4 µg/L (Truscott, 1981).

Two samples were examined for algal species and their quantity, to evaluate potential taste and odour problems. A sample taken March 25, 1981, showed two dominant species, both diatoms: Asterionella formosa (511 cells/mL) and Rhizosolenia eriensis (504 cells/ mL). Neither species is associated with taste or odour problems. On June 16, the dominant species were Rhizosolenia longiseta (318 cells/mL), Dinobryon bavaricum (111 cells/mL), and Asterionella formosa (96 cells/mL). Dinobryon has on some occasions been reported to cause taste and odour in water supplies (Palmer, 1962).

6. DISCUSSION & RECOMMENDATIONS

It would appear that Lake Maxwell has, in general, good water quality and a reasonable water yield. Lake Maxwell is the only lake on Saltspring Island which provides a bulk drinking water supply of good quality. St. Mary Lake, Cusheon, and Weston Lakes all have much higher algal growth and poorer water quality than Lake Maxwell (Goddard, 1975; Boyd, in prep.). The smaller lakes on the island (Stowell, Ford, Bullock's and Blackburn) also have a number of shortcomings in terms of drinking water sources (McKean, 1980). It would seem important then, that Lake Maxwell and, in particular, its watershed, be protected so that water quality can be maintained without deterioration. This has been recognized by Islands Trust in the large minimum lot size allowed in the watershed.

However, it should be emphasized that the lake is considered sensitive to watershed disturbance for a number of reasons. The watershed of the lake is relatively small (in comparison to the lake surface area) and as such, the lake is far more likely to respond to perturbations in the watershed. The water input to the lake is relatively low, thus the bulk water residence time ("flushing" time) is long. As a consequence organic material and nutrients will stay within the lake rather than passing through it, as would be the case with a well flushed lake. Increased accumulation of organic material will increase the hypolimnetic oxygen depletion rate and cause an acceleration of the eutrophication process.

Another reason for protection of the watershed is the relatively low nutrient content of the lake. Increased nutrient input affects a lake with low concentrations much more than a lake which already receives a relatively high nutrient loading. Because Lake Maxwell is presently at the lower limit of concentrations of nutrients and algae which begin to cause problems in drinking water supplies (taste, odour, filtration), any additional nutrient input should be avoided.

Nutrient inputs from the watershed originate not only from obvious sources such as septic tanks but from other activities as well. Road construction, logging, land clearing, ditching and drainage all contribute significant amounts of nutrients and suspended sediments to a lake.

There is little surface runoff from naturally treed watersheds during periods of normal rainfall, and nutrient cycles are "tight" with few nutrients being lost to drainage waters (Likens and Bormann, 1974; Bormann et al., 1977). When natural vegetation is removed, instabilities in the terrestrial environment result. These instabilities disturb the equilibrium in the aquatic environment (Karr and Schlosser, 1978). Readily observed disequilibrium is indicated by rapid runoff and large amounts of nutrients and sediments lost from the terrestrial to the aquatic component of the ecosystem, often over short time periods (Hobbie and Likens, 1973; Likens et al., 1978).

The above reasons indicate that it would be prudent to consider carefully any activities within the Lake Maxwell watershed, as in its present condition it provides the only source of high quality water on Saltspring Island.

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