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VANCOUVER LAKE: PRE-RESTORATION STATUS AND RESTORATION PROGRESS REPORT

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ABSTRACT

Water samples collected weekly or biweekly from Vancouver Lake beginning July 10, 1981, were analyzed for turbidity, suspended solids, alkalinity, dissolved oxygen, pH, nitrogen, phosphorus, conductivity, algae, and total chlorophyll. Measurements were made in the lake for water temperature, depth and Secchi disc depth. Results of the analyses indicate that Vancouver Lake is a nutrient-rich, productive, eutrophic lake. Because it is shallow during most of the summer, the lake does not stratify and does not develop anoxic conditions at the sediment-water interface. Bottom sediments are frequently mixed into the water column because the lake is shallow and exposed to frequent winds. The water regime and chemistry of the lake appear to be controlled by a complex interaction between the varying flow of Columbia River water into and out of the lake, the chemistry of the major influent stream, Burnt Bridge Creek, and the effects of very large populations of algae that occur during the summer. Vancouver Lake is unusual because it does not have large populations of blue-green algae or attached aquatic macrophytes, both of which would ordinarily be expected in a warm, shallow, nutrient-enriched lake. In May 1982, dredging began in the lake as part of the Vancouver Lake Restoration Project. During the summer of 1982, increased recreational use occurred in those areas already dredged. Suspended solids and algal cell density was lower in summer 1982 than in 1981, but transparency and turbidity remained at about the same level. This change in conditions is attributed to the effect of fine material suspended in the lake as a result of dredging.

INTRODUCTION

Vancouver Lake is located in the Columbia River floodplain, adjacent to the city of Vancouver in southwestern Clark County, Wash., within the greater Portland, Ore. metropolitan area (Fig. 1). The predominant land use adjacent to the lake is agricultural, although the south and west shorelines are included in a county park. Industrial activity related to the Port of Vancouver occurs south of the lake and includes a large aluminum smelter. The primary residential use close to the lake is in conjunction with farming. Additional residential areas are located on lowlands southeast of the lake and along the top of the east shore bluff.

The low-lying lands to the north, west, and south are subject to seasonal flooding from the Columbia River which flows within 1 mile of the southwest shore of the lake. These lowlands have an elevation of from 3 to 6 meters above mean sea level (msl). The northeast shore of the lake is formed by bluffs rising to an average elevation of 60 meters msl.

The climate of the region is maritime Mediterranean with moderately warm, dry summers and mild, wet winters. Seventy-five percent of the annual precipitation occurs between October and March. Annual total precipitation is approximately 100 cm.

Vancouver Lake has a surface area of 1,100 ha, is 4 km across from east to west, and has a mean shoreline length of about 12 km. The depth varies seasonally, ranging from a mean depth of less than 1 meter in September and October (maximum depths as low as .6 m have been recorded) to about 4 m in early June. The lake has a virtually flat bottom except for higher areas at the northern end caused by sedimentation of materials carried into the lake by Lake River (Fig. 2). These shallower areas are exposed during lowest water.

HYDROLOGY

The hydraulic regime of Vancouver Lake is complex and involves Burnt Bridge Creek, Lake River, Salmon Creek, and Columbia River (Fig.3).

Burnt Bridge Creek flows east through commercial and suburban sections of Vancouver and drains an area of approximately 70 square km. Mean annual flow is about 0.6 m/s, but flows are quite variable. Considerably higher flows are observed during rainfall. Burnt Bridge Creek flows are usually between 0.1 and 0.3 m/s (Dames and Moore, 1977.)

Lake River joins Vancouver Lake at its northern extremity and connects to the Columbia River approximately 14 miles to the north. The volume and direction of flow in Lake River is directly related to seasonal and tidal changes in the stage of the Columba River. During April and May while the Columbia River is rising because of spring runoff, Lake River flows south into Vancouver Lake with flows that reach 5.7 cu m/s. In late June the stage of the Columbia River drops rapidly and Lake River reverses to flow north out of Vancouver Lake. Flows during this period may reach 4.25 cu m/s.

During much of the year, August through March, the flow in Lake River is variable. It may reverse daily in response to tidal changes in the Columbia River, or it may flow north or south for several days at a time because of longer-term changes in the Columbia River resulting from weather or power generation.

Salmon Creek is a tributary of Lake River that drains a large rural and agricultural area north of Vancouver. It empties into Lake River about 3 km north of Vancouver Lake. Water from Salmon Creek can enter Vancouver Lake during southward flow of Lake River.

The Columbia River has an annual mean flow at Vancouver of 5,714 cu m/s. Flow is distinctly seasonal, as low

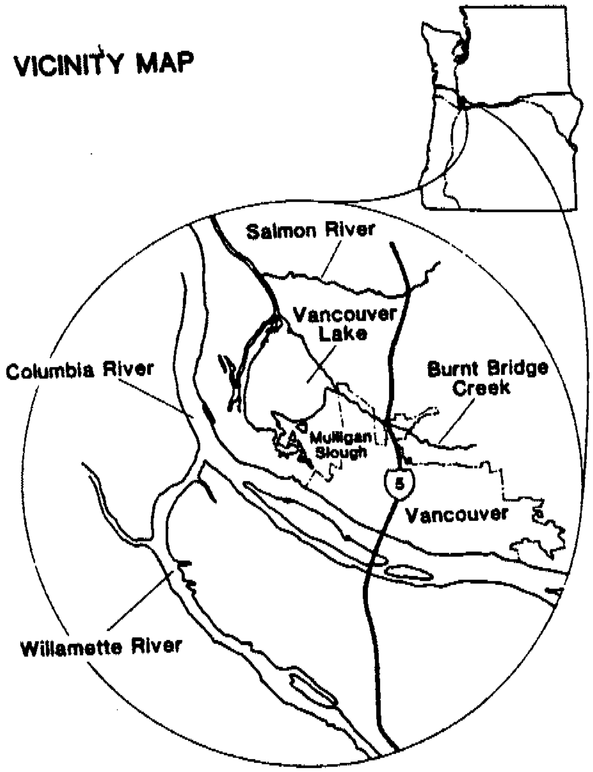

Figure 1.—Vicinity map of Vancouver Lake.

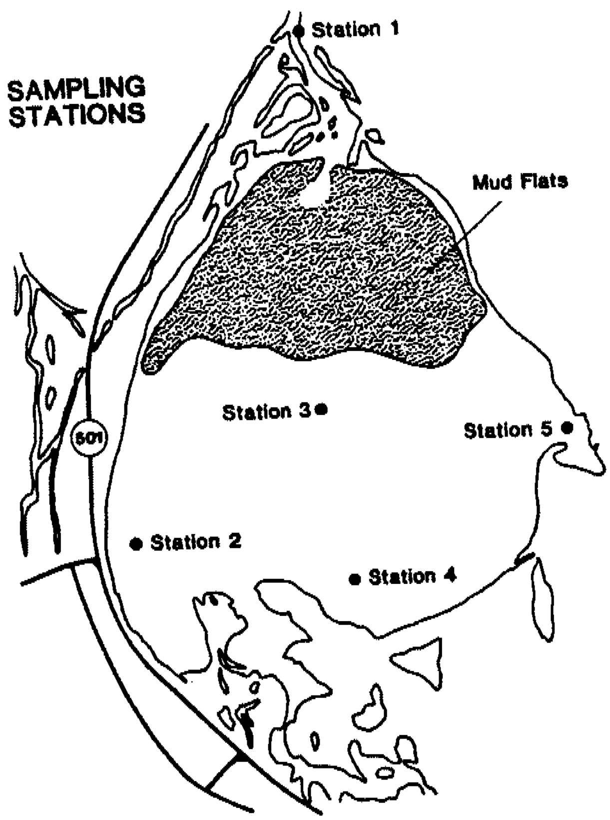

Figure 2.—Sampling stations in Vancouver Lake during restoration.

as 1,398 cu m/s in the fall and as high as 18,400 cu m/s during the spring snow melt.

Because of the great variation in flow, the level of the Columbia River at Vancouver changes considerably according to season. Mean maximum river stage is greater

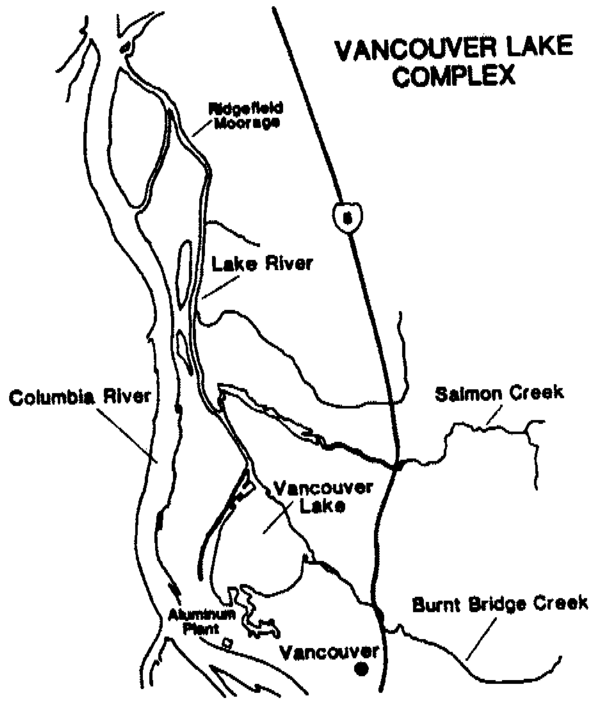

Figure 3.—Vancouver Lake and associated waterways.

than 4.6 meters msl, while during August river stage may fall as low as 0.6 meters msl.

During low water in late summer, the tide fluctuates daily in the Columbia River stage near Vancouver by approximately 0.6 meters.

The hydrology of Vancouver Lake is directly controlled by the stage of the Columbia River (Fig. 4). The lake is at its lowest level in late October. Flow in Lake River can reverse daily in response to tidal fluctuations in the Columbia River. As the Columbia River and flow in Burnt Bridge Creek begin to rise from the winter rains, the lake level rises accordingly to an intermediate level with perhaps a mid-winter peak following particularly heavy rain. Flow in Burnt Bridge Creek increases rapidly as the rainy season begins. Between November and February the flow in Lake River is frequently reversed and may flow into Vancouver Lake for several days at a time. The effects of tidal fluctuations diminish as the river stage rises.

In late spring (April-May) the Columbia River rises in response to snowmelt runoff. During this time, until the

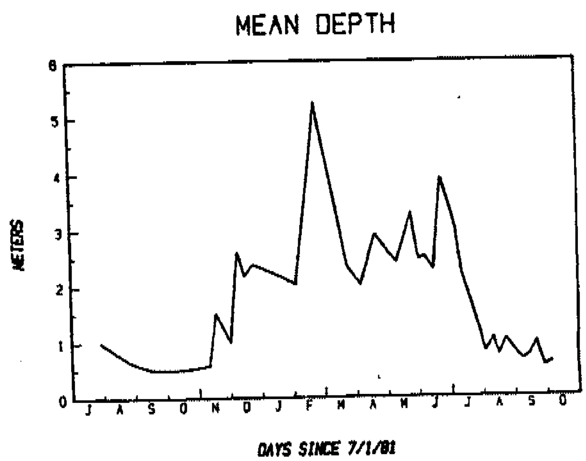

Figure 4.—Depth of Vancouver Lake. The reported value is the mean of depths at stations 2, 3, and 4.

highest water in mid-June, flow in Lake River is south into Vancouver Lake. The volume of water in the lake may increase fourfold from November through early June (8.5 to 35 million cubic m). From mid-June to mid-July the lake level drops rapidly from its high mark of around 3.7 meters msl to near the annual low of 1.0 meters msl. During this time, Lake River flows north, carrying water away from the lake.

From July to December the lake remains at a low level, fluctuating around 1 to 1.7 meters msl elevation. While the flow in Lake River may reverse daily in response to Columbia River tidal fluctuation, it is not clear if water from the Columbia River is actually reaching the lake during this period.

WATER QUALITY

As part of the water quality monitoring program of the Vancouver Lake Restoration project, water samples have been taken weekly or biweekly at several sites in the lake and in Lake River. Sampling began July 10, 1981, and will continue until 1 year after completion of construction on the project. Table 1 gives summary values for the parameters surveyed. These results characterize Vancouver Lake as a shallow, turbid, nutrient-rich, eutrophic lake.

Because of its temperate climate and complex hydrology, many of the parameters in Vancouver show a seasonal cycle. To more clearly show this seasonal variability, mean values of data from three stations in the lake (Stations 1, 2, and 3) are represented graphically in Figures 5 through 24. Figure 2 shows station locations.

Vancouver Lake remains completely mixed almost continuously because it is so shallow and is exposed to frequent winds. As a result, the lake temperature is very closely coupled to air temperature. Daily temperature variations near the surface of 8° Celsius were recorded during warm summer days. Daily temperature variation near the bottom was as much as 6° C. In all cases, the lake cooled enough during the night to become isothermal on all but the calmest days. The greatest difference between surface and bottom minimum temperature observed to date has been 2°C. The maximum lake water surface temperature was 28° C in September 1981. Minimum water temperature recorded was 6° C in December 1981. The lake surface froze completely on January 8, 1982 and remained frozen for 7 days. The annual water temperature cycle is presented in Figure 5.

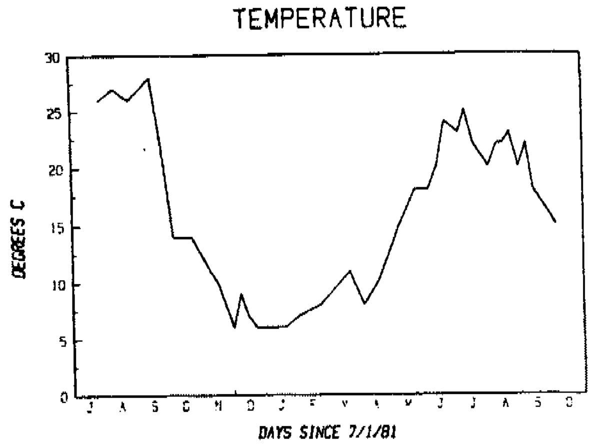

Figure 5.—Midday surface water temperature at Vancouver Lake measured at 0.3 m depth.

Other parameters whose variability seems to be primarily related to the seasonal cycle are conductivity and alkalinity. Conductivity decreases steadily throughout the fall, reaching a low value in January (Fig. 6). This occurs before there has been a significant influx of water from the Columbia River, and the value is lower than the normal mean conductivity in the Columbia in January of about 100 μmhos/cm (Portland G. E. Co., 1981). This decline in conductivity is probably caused by dilution by low conductivity rainwater from Burnt

Table 1. — Water quality data. Values for Vancouver Lake are means of all weekly or biweekly samples taken between July 10, 1981 and Oct. 5, 1982. Values for the Columbia River are annual means from Portland G. E. Co. (1981).

Station Parameters	Units	Vancouver Lake					Columbia River
		1	2	3	4	5	—
Dissolved oxygen	mg/l	9.6	10.2	9.9	10.0	10.7	10.7
Temperature	degrees C	15.5	17.2	15.6	16.4	16.6	11.6
pH	units	7.5	7.8	7.8	7.8	8.0	7.8
Conductivity	μmhos/cm	137	142	139	141	152	135
Suspended solids	mg/l	49	80	62	71	57	—
Turbidity	NTU	57	72	66	71	44	15
Alkalinity	milli eq./l	1.07	1.11	1.04	1.08	1.14	0.97
Secchi depth	m	0.37	0.32	0.35	0.31	0.37	0.84
NO_3N	mg/l	0.369	0.174	0.250	0.225	0.345	0.25
NH_3N	mg/l	0.233	0.175	0.150	0.162	0.150	0.07
Kjeldahl N	mg/l	1.44	1.65	1.34	1.56	1.80	—
Organic N	mg/l	1.71	1.46	1.07	1.31	1.56	—
NO_2N	mg/l	0.008	0.004	0.004	0.002	0.003	0.01
PO_4P	mg/l	0.062	0.040	0.033	0.056	0.025	0.066
Total P	mg/l	0.193	0.218	0.219	0.225	0.228	0.08
Chlorophyll	mg/cu m	51	60	50	60	80	12
Algae	cells/ml	31,000	23,000	28,000	29,000	33,000	1,800
Depth	m	—	2.03[1]	1.15	1.88	1.54	—

[1] Deepened by dredging

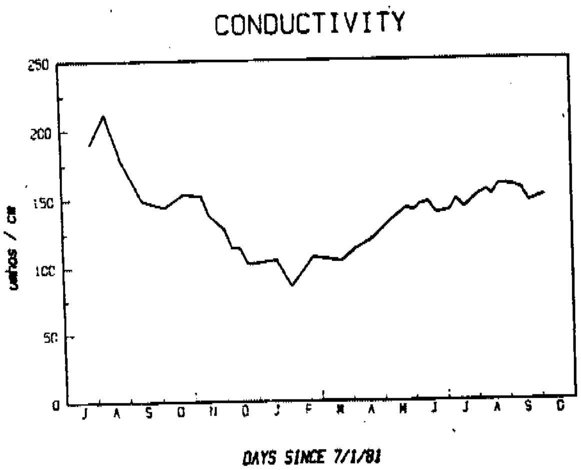

Figure 6.—Conductivity of surface water in Vancouver Lake; mean of stations 1, 2 and 3.

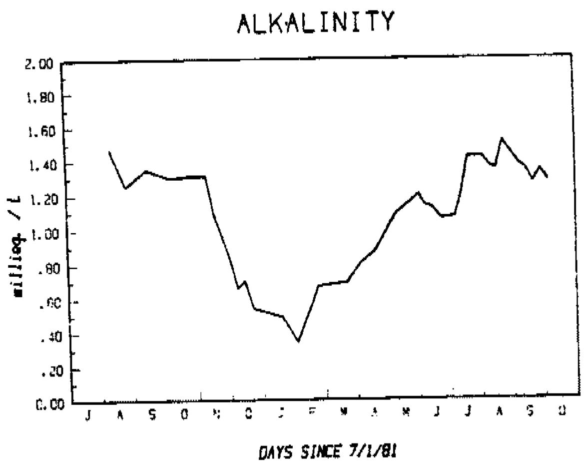

Figure 7.—Alkalinity of surface water in Vancouver Lake; mean of stations 1, 2 and 3.

Bridge Creek. Evidence to support this comes from September 1982 when the conductivity at Station 5 declined sharply following several days of heavy rains. This drop corresponded with a similar but smaller magnitude drop in Vancouver Lake.

Alkalinity follows a curve very similar to conductivity. The alkalinity drops during the winter while the pH remains relatively constant, indicating a response to dilution (Fig. 7).

PHYTOPLANKTON

Phytoplankton density in Vancouver Lake is high (Fig. 8). Cell density, averaged for the three stations in the lake proper, reached 200,000 cells per milliliter in August 1981. Chlorophyll concentration is correspondingly high (Fig. 9). This high density limits the recreational potential of the lake, and also influences some aspects of water quality.

Total suspended solids, turbidity, Secchi disc depth, dissolved oxygen, and pH are all influenced directly by the number and activity of algal cells in the lake. There is a significant correlation between algal cell density and total suspended solids ($r^2 = 0.8755$, $p < 0.001$), and between algal cell density and Secchi disc depth ($r^2 \cdot -0.7118$, $p < 0.01$).

The activity of large numbers of algal cells is also evident in the pH and dissolved oxygen values (Fig. 10 and 11). Most samples were taken near midday during maximum photosynthesis. During the period of peak algal densities, pH during the day exceeded 9.0 and dissolved oxygen content reached

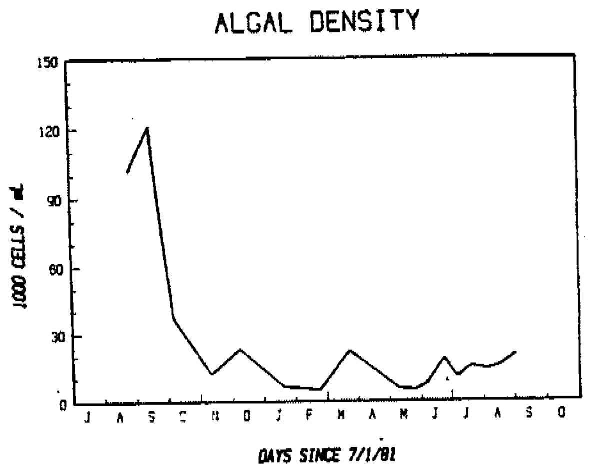

Figure 8.—Algal cell density in Vancouver Lake; mean of stations 1, 2, and 3. For solitary species each cell is counted, for typically colonial forms each colony is counted as one unit.

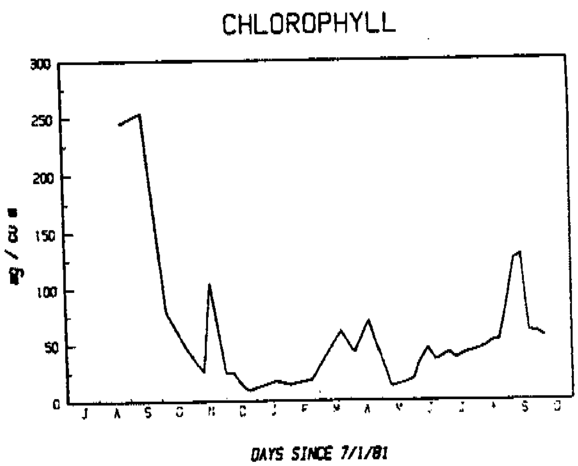

Figure 9.—Total chlorophyll concentrations in Vancouver Lake; mean of stations 1, 2, and 3. Chlorophyll is measured by *in vivo* fluorescence and adjusted to chlorophyll using methods of Strickland and Parsons (1972). The values are not corrected for chlorophyll degradation products.

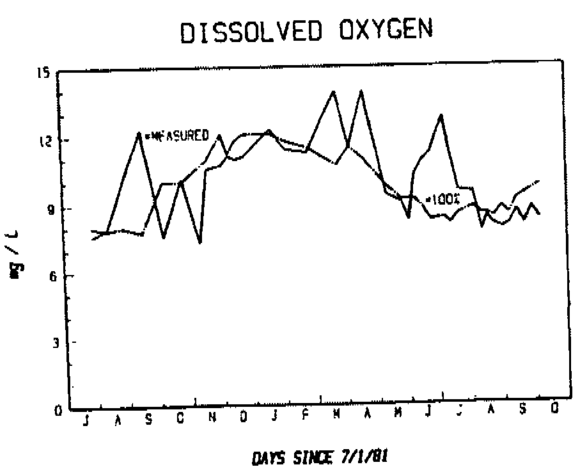

Figure 10.—Midday dissolved oxygen in Vancouver Lake; measured at 0.5 meter depth, or halfway between surface and bottom, whichever is less. Measurements were made by polarographic technique.

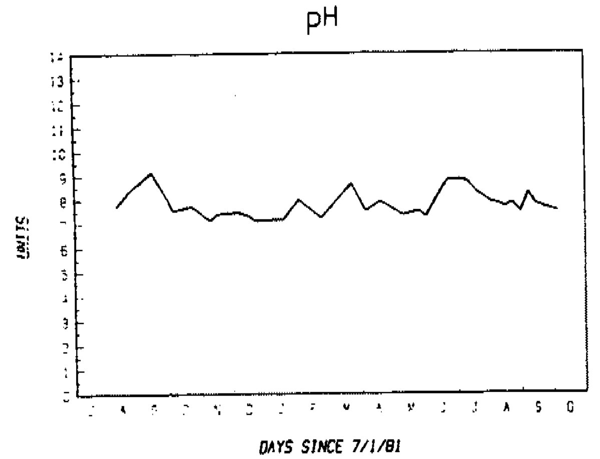

Figure 11.—Midday pH in Vancouver Lake; mean of stations 1, 2, and 3.

154 percent saturation. No data on diurnal variation in dissolved oxygen are as yet available.

By far the most common species in the phytoplankton is a diatom, *Synedra fasiculata* var. *truncata*. Next in abundance are members of the diatom genus *Stephanodiscus*. Other commonly occurring algae include members of the genera *Nitzschia*, *Navicula*, and *Fragilaria*, as well as *Cyclotella glomerta*, *Cryptomonas erosa* and *Rhodomonas minuta*; all except the last two are diatoms. *Cyclotella glomerata* sometimes replaces *Synedra fasiculata truncata* as dominant at the mouth of Burnt Bridge Creek (Station 5). This station is heavily influenced by the flow from the creek and shows several differences from the stations in the lake. Although occasionally wind causes local high densities of blue-green algae, blue-greens were a minor component of the phytoplankton, rarely comprising more than 5 percent of the total count and usually less than 2 percent. Table 2 lists species comprising at least 1 percent of at least one sample.

Also included in Table 2 is the relative frequency of occurrence of each species in all the samples and its mean rank in the samples in which it appeared. In this tabulation, a species with a low frequency of occurrence would be expected to also have a low mean rank. A low frequency combined with a relatively high rank would indicate a species that was either abundant but present at only one station, or abundant at several stations, but only for a short period of time.

The composition of the phytoplankton in Vancouver Lake is interesting in several respects. The cell density is very high, up to 250,000 cells/ml. The most abundant alga in the lake, *Synedra fasiculata* var. *truncata*, has not been found in any of the 100 lakes and rivers in the Northwest previously observed or reported in the literature (Sweet, 1982). Another feature is the insignificance of blue-green algae in the lake. Blue-green algae are normally abundant in a shallow, warm, nutrient-rich lake with relatively high pH such as Vancouver Lake.

Synedra fasiculata var. *truncata* develops best in water of high conductivity, or in slightly brackish water. The two locally common *Stephanodiscus* species, *S. ambigua* and *S. hantschia*, are typical of eutrophic waters, both in lakes and rivers. *S. ambigua* is dominant at times in hypereutrophic Upper Klamath Lake. *S. hantschia* is more typical of mesotrophic-eutrophic rivers, but has been found in a shallow hypereutrophic pond at very high densities (Sweet, 1982). Both *Stephanodiscus* species are very common, at times dominant, in the Columbia River. The pennate diatoms *Nitzschia*, *Navicula*, and *Fragilaria* are periphytic algae commonly found in enriched streams.

Cyclotella glomerata is the only alga in Vancouver Lake that repeatedly replaces *Synedra fasiculata* as dominant, and this occurs only at the mouth of Burnt Bridge Creek (Station 5). *Cryptomonas erosa*, *Rhodomonas minuta*, and *Nitzschia palea* are at times fairly common. These three algae are typically associated with organic-rich waters, *Nitzschia palea* especially with organic pollution. *N. palea* is more common at Station 5 than at the other stations.

Three algal blooms were noted in the lake (Fig. 8). The earliest occurred in March when *Stephanodiscus astrea* var. *minutula* increased dramatically, becoming the dominant (most common) species for a short period. This species is present in the Columbia River, and also in Vancouver Lake during much of the year. The second bloom, an increase in the abundance of *Aphanazomenos flos-aquae*, came later in the summer, in late June 1982, somewhat later in 1981, and represents an increase in the abundance of *Aphanazomenos flos-aquae*. This increase in *A. flos-aquae* occurs just after the major influx of Columbia River water to the lake. During this bloom *Aphanazomenon* becomes the most common species at some stations because of wind-blown concentrations. In the past two summers these have been quite localized and in general have not reached objectionable proportions. The *Aphanazomenon* bloom quickly fades to be replaced by a dramatic increase in the numbers of *Synedra fasiculata* var. *truncata*. This alga is always present in the flora of Vancouver Lake, is usually the dominant species, and during its peak growth, commonly comprises 60 to 80 percent of the total cell count. It rarely accounts for less than 30 percent of the cell count.

The algae indicate that Vancouver Lake is nutrient-enriched (nutrients are not limiting growth) and that the in-

Table 2. — Algal taxa comprising at least 1 percent of at least one phytoplankton sample. Relative frequency is the percent of all samples in which the taxon appeared at greater than 1 percent. Mean rank is the arithmetic mean of the taxon's rank in the samples in which it appeared.

Species	Relative frequency	Rank
Synedra fasiculata truncata	96	1.27
Stephanodiscus astrea minutula	92	3.93
Staphanodiscus hantzschii	96	4.33
Fragilaria construens	92	5.75
Cyclotella glomerata	69	5.84
Rhodomonas minuta	55	6.00
Melosira ambigua	55	6.64
Nitzschia acicularis	55	6.68
Cryptomonas erosa	49	8.86
Melosira distans	39	8.59
Ankistrodesmus falcatus	36	8.25
Anabena sp.	34	6.73
Navicula minuscula	31	6.00
Nitzschia palea	26	6.64
Nitzschia frustulum	24	10.50
Aphanzomenon flos-aquae	22	3.56
Chodatella Wratlawiensis	22	8.11
Chlamydomonas-like	22	10.67
Melosira granulata angustissima	20	7.88
Miscellaneous green algae	16	10.83
Nitzschia holsatica	14	7.80
Scenedesmus quadricauda	14	9.80
Stephanodiscus subsalsus	12	7.33
Melosira italica	12	8.75
Scenedesmus abundens	12	12.23
Nitzschia sp.	10	15.00

Table 2. (Continued)

Species	Relative frequency	Rank
Acnanthes linearis	8	7.00
Selenastrum minutum	8	8.75
Synedra radians	8	9.75
Nitzschia paleacea	8	12.25
Cyclotella Kutzingiana	6	8.00
Navicula muralis	6	9.50
Melosira granulata	6	10.00
Oocystis pusilla	6	11.33
Fragilaria pinnata	6	12.67
Scenedesmus acuminatus	6	13.33
Gomphonema angustatum	4	6.50
Acnathes lanceolata	4	8.00
Miscellaneous blue-green algae	4	8.50
Navicula pupula	4	9.50
Miscellaneous pennate diatoms	4	10.00
Kephyrion spirale	4	10.50
Trachelomonas volvocina	4	11.00
Tetraedron regulare	4	11.50
Navicula cryptocephala	4	11.50
Acnanthes minutissima	4	12.00
Asterionella formosa	4	12.00
Nitzschia amphibia	4	13.00
Tetrastrum staurogeniaeforme	4	13.00
Navicula sp.	4	14.50
Cyclotella pseudostelligera	2	8.00
Cyclotella meneghiniana	2	9.00
Sphaerocystis schroeteri	2	9.00
Stephanodiscus astrea	2	11.00
Mallomanas sp.	2	12.00
Crucigenia quadrata	2	13.00
Nitzschia dissipata	2	13.00
Synedra delicatissima	2	13.00
Synedra ulna	2	14.00
Amphora perpusilla	2	14.00
Navicula viridula	2	15.00
Navicula mournei	2	16.00
Navicula minima	2	16.00
Cymbella minuta	2	20.00
Nitzschia filiformis	2	21.00
Fragilaria vaucheriae	2	22.00
Rhoicosphenia curvata	2	23.00
Nitzschia clausii	2	25.00

flow from Burnt Bridge Creek may be loading organic pollution and associated elements into the lake.

An unusual aspect of the biota of Vancouver lake is the absence of aquatic macrophytes in the lake. A lake as shallow, warm, and nutrient-rich as Vancouver Lake would ordinarily be expected to exhibit extensive growth of attached aquatic plants. Vancouver Lake as yet has none.

Three conditions of the lake may provide a plausible explanation. The low transparency of the water during the summer may limit light penetration to such an extent that plants on the bottom lack sufficient light for photosynthesis. An alternative, or perhaps additional, explanation may lie in the repeated disturbance of the bottom sediments by wave action and fish, which may make it impossible for attached plants to become established. The third factor that could limit macrophyte growth is the seasonal variation in depth of the lake.

A severe problem currently limiting the recreational potential of Vancouver Lake is the low transparency of the water. Secchi disc readings as low as 0.05 m have been recorded during the summer (Fig. 12). The high algal population is a major contributor to this problem, but not the only one. The shallow water permits bottom sediments to be stirred easily into the water column by even moderate winds. The magnitude of this problem is indicated by the sharp rise in suspended solids in November following 2 days of high wind (Fig. 13). This reduced the Secchi disc transparency from near 0.30 m to less than 0.10 m.

Another major influence in keeping sediments suspended in the lake is the large population of carp. In the shallower parts of the lake it is easy to follow the movements of fish by the "smoke trails" of suspended sediments they leave behind.

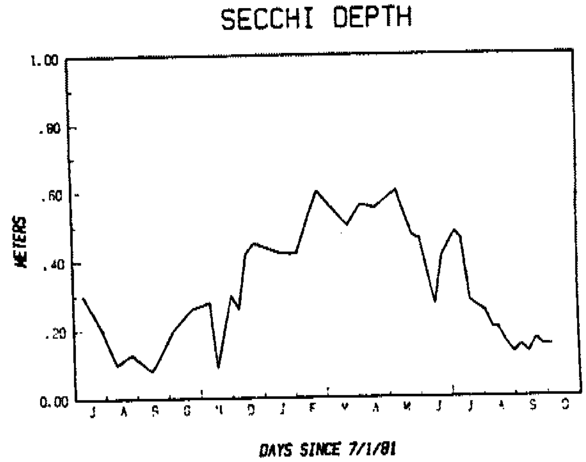

Figure 12.—Secchi disc depth in Vancouver Lake, mean of stations 1, 2, and 3.

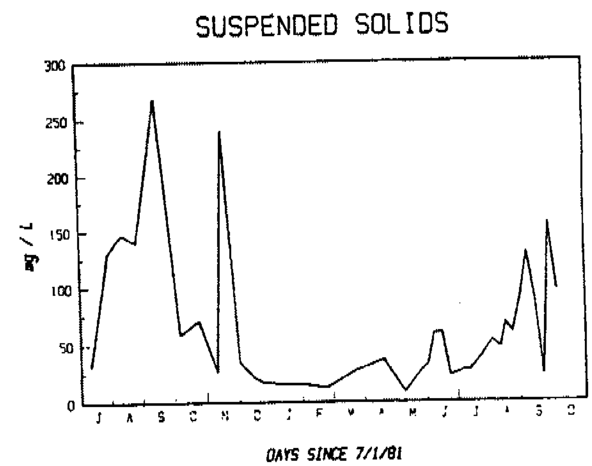

Figure 13.—Total suspended solids (nonfilterable solids) in Vancouver Lake; mean of stations 1, 2, and 3.

NUTRIENTS

Nutrient concentrations in Vancouver Lake are high (Table 1) with phosphorus higher than nitrogen in relation to algal needs. The molar ratio of inorganic nitrogen to total phosphorus is approximately 3:1. The ratio of total nitrogen to total phosphorus on a weight basis is approximately 9:1. Both these ratios indicate that phosphorus is unlikely to be a limiting nutrient in this system.

Both ortho and total phosphate are at their highest concentrations during the summer when water is shallow, temperatures warm, algal numbers high and fish very active (Fig. 14). Both Burnt Bridge Creek and the Columbia River are high in phosphorus and could be sources for Van-

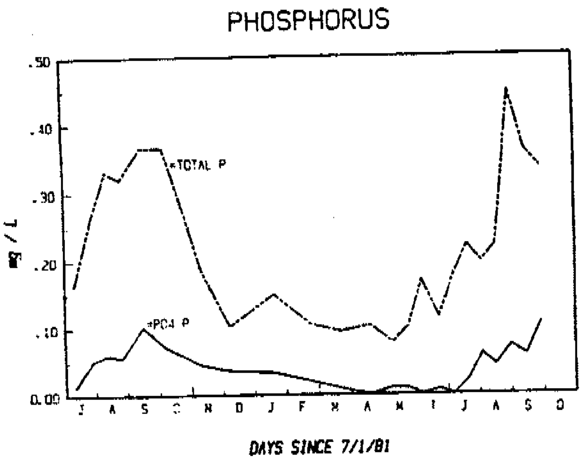

Figure 14.—Phosphorus concentrations in Vancouver Lake; mean of stations 1, 2 and 3. Values are reported as mg P/l.

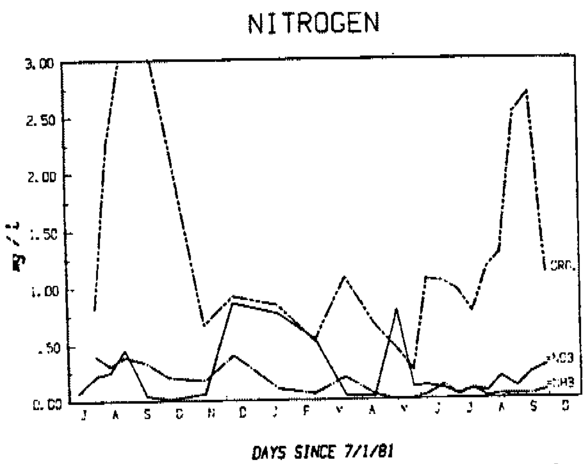

Figure 15.—Nitrogen concentration in Vancouver Lake; mean of stations 1, 2 and 3. Values are reported as mg N/l. "ORG" is total organic nitrogen.

couver Lake. A detailed nutrient budget has not been prepared for Vancouver Lake, but it appears that much of the phosphorus load in the lake comes from internal cycling from the sediments. Bottom feeding fish cause this cycling.

Organic nitrogen follows a pattern very similar to algal cell density (Fig. 15). It is likely that most of the organic nitrogen is found in the algal biomass.

Ammonia and nitrate nitrogen follow a somewhat different annual pattern, being relatively low in the summer and increasing in the winter months. The increases in ammonia and nitrate occur when inflow from Burnt Bridge Creek is most influential on the lake. It seems likely that the increases in nitrate and perhaps ammonia can be traced to increased input from Burnt Bridge Creek as flow increases. In September 1982, a large increase in nitrate concentration at Station 5 (Burnt Bridge Creek) was observed following high flows resulting from heavy rain.

RESTORATION

Many plans have been proposed in the past to increase the use of Vancouver Lake (U.S. Environ. Prot. Agency, 1978). In the 1920's local farmers wanted the lake drained for cropland use. The plan was never carried out, and in 1948 it was proposed that Vancouver Lake be dredged to a depth that would permit the mothballing of Liberty Ships there. The Port of Vancouver and the Vancouver Chamber of Commerce supported this plan which included minor recreational development. In 1966 the Port of Vancouver prepared another development plan which included construction of a barge canal into the lake and barge-loading facilities within the lake. Significant recreation facilities were included in this plan.

In 1968 the Port of Vancouver proposed a new development plan that emphasized recreation. About this time the Port contracted with Washington State University to conduct water quality studies of Vancouver Lake and to propose methods for rehabilitation. The result of these studies (Baghat and Funk, 1968; Baghat and Orsborn, 1971; Orsborn, 1972) was a proposal to dredge the lake to remove nutrient-laden sediments, provide flushing water from the Columbia River, and to implement controls on the nutrient inputs to the Lake from Burnt Bridge Creek.

After several modifications of scope and design, the three-pronged approach recommended by Washington State University was proposed in a grant application to the EPA Clean Lakes program (Dames and Moore, 1977). This document proposed dredging between 9 and 11 million cubic meters of sediment from the lake, connecting the lake to the Columbia River via a combination of open channel and culverts to admit up to 17 cu m/s of river water, and implementing nutrient runoff control measures in the Burnt Bridge Creek basin.

After review by EPA and interested groups, and based on information from the lake dilution project at Moses Lake, Wash. (Welch, 1979), a final Operations Plan (Dames and Moore, 1980) was prepared to guide the design and implementation of the restoration project. This final plan modified dredge disposal areas to preserve critical wildlife habitat, reduced dredging to 6.5 million cubic meters to comply with EPA requirements, and reduced the number of culverts to provide a maximum of 9 cu m/s between 3 percent and 5 percent flushing volume per day, depending on lake and river levels. Tide gates in the channel prevent backflow through it from Vancouver Lake to the Columbia River, and sluice gates permit the channel to be closed entirely as necessary to protect anadromous fish runs or to prevent highly turbid flood waters from entering the lake.

The dredging plan, as finally implemented, is designed to facilitate the flow of higher quality Columbia River water to those areas of the lake most heavily used for recreation and to provide a "short circuit" flow for Burnt Bridge Creek water to Lake River (Fig. 16).

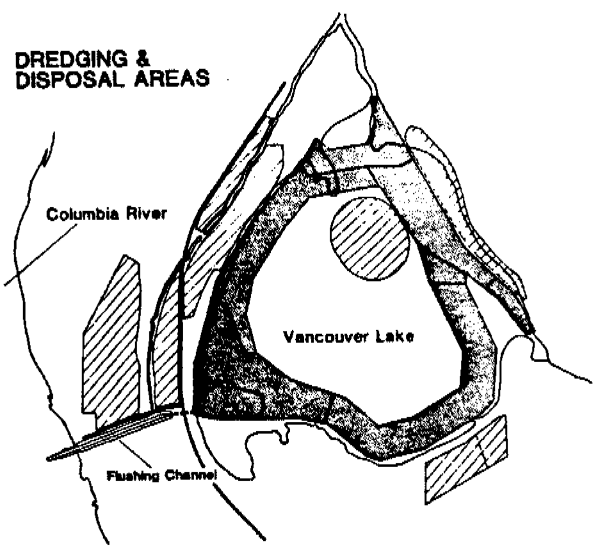

Figure 16.—Dredging and disposal areas for the Vancouver Lake Restoration Project.

A project of this magnitude was possible because land suitable for dredge material disposal was available near the lake. Some land was owned by the Port, some was donated by other large landowners in the area, and easements were obtained from landowners for the remaining sites.

Water from the dredge is returned to the lake after settling in the disposal areas and secondary settling ponds, with silt barrier curtains used around the return flow outfall as needed to maintain water quality. The contract specifies water quality standards to be maintained in the return flows and lake during construction; a water quality monitoring program monitors the construction progress.

A major concern throughout the development of the Vancouver Lake Restoration plan has been the effect that dredging and its resultant disturbance might have on the fish in the lake, and the effect that the altered flow, resulting from the flushing channel, might have on the migration of anadromous fish in the Columbia River. To help answer these questions, a fisheries monitoring plan was developed. This plan is being carried out by Envirosphere Inc., of Seattle. Table 3 presents preliminary results of their initial sampling efforts.

Samples were taken by beach seine and gill net in April. Since then samples have been taken by beach seine only. A surprising result was the large number of juvenile salmon in the lake in the spring. Most of the salmon were caught along the steeper northeast shore.

In the early samples, yellow perch were concentrated in the south of the lake near the entrance to Mulligan Slough, the low-lying flooded ground to the south of Vancouver Lake. This area is the spawning ground for many of the fish species in the lake. In later samples, most of the yellow perch caught in the seine were young of the current season.

Many carp are in the lake, enough to support a small commercial fishery. Other catches of note include an 1.3 m sturgeon pumped through the dredge, and several sub-legal sturgeon (less than 1 m length) found in the possession of the carp fishermen. Recently, shad have been caught in the lake.

EFFECTS OF CONSTRUCTION ACTIVITY

Dredging started in the lake in late May 1982. As of Oct. 15, 1982, dredging was 35 percent complete. The Flushing Channel between the lake and the Columbia River was opened following ceremonies Oct. 22, 1982. At this time it is not possible to determine what long-term effects the restoration will have on the lake.

Some effects noted thus far are increased recreation on the west side of the lake along the county park, decreased algal densities throughout the lake, and an apparent qualitative change in the relationship between turbidity and suspended solids.

The most obvious effect of the dredging has been to make the lake deeper. Although the change has been relatively small in terms of possible limnological effects, dredging along the west side of the lake has increased the summertime water depth from approximately 0.5 m to nearly 2.0 m. This has permitted increased recreation, and even though the project is far from complete, area residents are already taking advantage of the opportunities.

Summertime algal densities in 1982 did not reach the high values of 1981. Suspended solids concentrations were also lower in 1982 than in 1981. Turbidity and Secchi disc depths were very close to the values of 1981. This contrast of lower suspended solids with the same Secchi disc values stems from a change in the nature of the suspended material. The suspended material in 1982 was more finely divided. This is apparently the result of fine material from the dredge return flow remaining in suspension, or being resuspended in the lake. This source of turbidity kept the water transparency at levels similar to 1981 while greatly reducing algal cell densities.

It is not known if the reduced algal counts result from light limitation caused by the increased turbidity from dredging,

Table 3. — Fish species caught by beach seine in Vancouver Lake. Values are the total number caught at all stations in the lake.

	DATE					
Species	4-7-82	4-22-82	5-11-81	5-27-82	6-8-82	9-22-82
Chinook salmon	52	54	13	12	8	—
Yellow perch	37	33	6	27(1)	187(1)	18(1)
White crappie	5	28	1	14	39	227
Black crappie	1	8	3	7	19	520
Pumpkin seed	2	2	5	3	3	5
Peamouth	3	17	190	9	65	6
Carp	4	12	10	5	27	70
Northern squawfish	2	7	5	3	71	—
Prickly sculpin	1	—	3	17	10	4
Mountain whitefish	0	—	—	—	—	—
Largescale sucker	0	9	20	5	42	1
Largemouth bass	0	4	9	4	11	59
Brown bullhead	0	1	1	1	12	—
Other sculpin	—	—	14	—	—	—
Walleye	—	—	—	1	—	—
Stickleback (3 spine)	—	—	—	5	23	—
Bluegill	—	—	—	—	1	24
Goldfish	—	—	—	—	7	—
American shad	—	—	—	—	—	1
Warmouth	—	—	—	—	—	1
TOTAL	106	175	280	113	525	936

(1) Mostly young of this season

or if the algae decreased because of other factors such as cooler temperatures. In any event, water transparency has not changed significantly during construction.

Changes in Vancouver Lake as a result of the Restoration Program are anticipated to increase the value of the lake as a recreational resource in the Portland-Vancouver metropolitan area. Improvements will make the lake more usable during the summer months because of increased depth from the dredging, and improve the water quality by introducing higher quality Columbia River water. The improvements resulting from the addition of Columbia River water will result primarily from increased flushing of the system rather than dilution because the nutrient content of the lake and river are similar.

Changes in the Burnt Bridge Creek watershed to reduce the use of septic systems, increase sewers, and reduce other sources of nonpoint pollution are expected to decrease the influx of nutrients to the lake.

CONCLUSIONS

The Vancouver Lake restoration is a major structural modification of a lake aimed at improving its recreational potential. Construction is well underway and progressing well. Water quality sampling indicates that construction has affected the lake only in minor ways. Noticeable effects from the restoration effort have not yet been detected. The increased depth in the areas dredged to date has increased recreational use of the lake.

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