Water Quality at Aquatic Park

Rezwan Razani

Introduction

In 1986 the City of Berkeley hired a consultant to propose a new Master Plan for Berkeley's Aquatic Park. The city wishes to expand the use of this Park, which suffers a bad reputation as unsafe, inaccessible, and unclean. As the Park is over 70 percent water, improvement and proper management of water quality is an integral part of its upgrading. Aquatic Park is located in West Berkeley, cut off from the Bay by the Eastshore Freeway. Since circulation is limited and sources of water are urban runoff and water from the Bay, water quality is questionable. This paper is an analysis of Park water quality in order to assess its suitability for human recreation or as a wildlife habitat. The paper synthesizes information drawn from historical water quality investigations and problems. Also, I conducted tests of selected chemical and physical parameters to determine the current water quality. Particular emphasis is placed on the difference in water quality between the separate lagoons in the Park, and what this indicates about water circulation within the Park.

Past Studies

In the late summers of 1967 and 1969, Aquatic Park suffered major fish kills. The City of Berkeley did several studies to ascertain the cause of death and to estimate water quality (Beers and Wistrom, 1969). Grove (1969) conducted a study of water inputs to the Park from outfalls flowing from the industries of West Berkeley into the eastern shore of Aquatic Park. Altamirano (1983) studied general Park water quality in the spring, and Betts (1983) studied coliforms as part of a study of Aquatic Park by the Environmental Science Senior Seminar at the University of California in Berkeley. Feldman from the RWQCB took grab samples of Aquatic Park water to test for PCBs and organic pesticides (1989, Pers. Comm.).

Background

Location: Aquatic Park is located in West Berkeley, bordered by I-80 on the west, and the original Bay shoreline and Santa Fe railroad on the east (Figure 1). It is one mile long and only 300 to 900 feet wide east to west. North and south property lines are Addison and Potter streets respectively. The City owns two lagoons (N and C, Figure 1). It does not own the southernmost

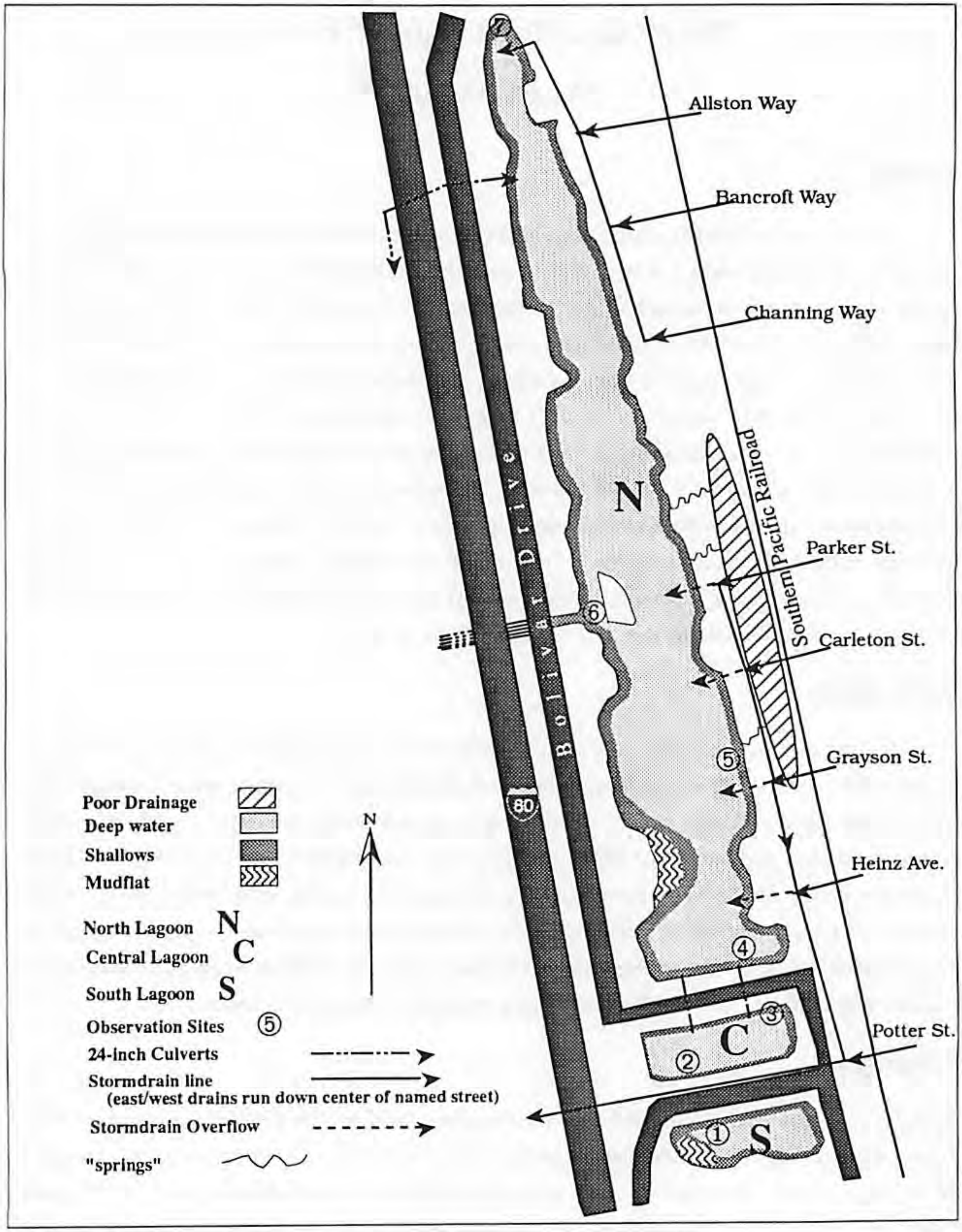

Figure 1. Aquatic Park map showing sample sites and circulation.
Source: Adapted from Ferlin (1983). Not drawn to scale.

lagoon (S, Figure 1), but I included it in my study for comparison. Lagoon S is owned by a radio station (Erickson et al., 1986).

Circulation: The flow of water into the Aquatic Park lagoons from the Bay is through a series of five 24-inch culverts with tide gates extending under the freeway at about the midpoint of the main lagoon, and one 24-inch culvert 900-feet from lagoon N's northernmost point (Figure 1). The culverts become clogged and are supposed to be cleaned out twice a year. Flows from the City into the Park are by way of storm drains running into the east side of the Park, and a few small "springs." The "springs" originate from a stagnant stretch of water on the far east side of the Park. Poor drainage may be the cause of this stretch of water, but it deserves further investigation.

Within the Park, the primary circulation occurs in the main body of the biggest lagoon (N, Figure 1). The middle lagoon is joined to lagoon N by two 18-inch pipes. These have not been cleaned for years. The southernmost lagoon is a tidal flat at low tide. There is a man-made connection between this lagoon and the Bay, and at low tide the water can be seen flowing through it. This connection is maintained by CalTrans (Raxter, 1988).

History of Aquatic Park Developments, Water Quality, and Maintenance: Aquatic Park was originally Bay shoreline. In 1936, the Eastshore Freeway was built, creating a lake between Ashby and University Avenues. The land surrounding the lake was acquired from Santa Fe in a land trade. Work began on Aquatic Park with the dredging of the lagoon and modification of the shoreline with land fill (Berkeley, 1945). For purposes of landscaping, the area was dredged and gypsum added in order to neutralize the salt. The area was watered heavily and left to dry, topsoil was added, and landscaping commenced. Also, a two-mile water main was installed for irrigation and to combat the salt (Cresswell, 1938).

During the 1950's, water quality deteriorated. The Park was invaded by *Ruppia maritima* (duckweed) which tended to grow enthusiastically, then decay. Furthermore, nearby industries began dumping their waste water into the lagoon (Ferlin, 1983). In 1960, the City of Berkeley tried to sell the Park. The Friends of Aquatic Park formed and successfully lobbied against this action.

The City then commenced efforts to improve Park water quality. In 1963 the tidegates were repaired. In 1964 the Park was again dredged to a depth of 6 to 8 feet, leaving the water "sparkling clean" (Grove, 1969). The duckweed problem resurfaced very quickly and was blamed for the 1967 fish kill. The herbicide Casoron W-50 was successfully used against it. However, the City decided that use of herbicides was not "humanitarian" (Berkeley, 1969).

Water quality was at an all time low. Coliform counts were in excess of water contact acceptability, and fecal strep counts indicated raw sewage pollution (Berkeley, 1969). To alleviate this condition, direct discharges of sewage from Park toilet facilities were abandoned. A pressure flap tidal system was constructed to allow water to flow into the Potter Street storm drain at certain tide levels to maintain lagoon water level. This was a "one-way" system, as water could not flow back from the sewer into the lagoon as before. A new tidal overflow wier was constructed north of the Boat House to aid in controlling lagoon water level and circulation. The main tide gates were to be changed from a flap to a weir system, but this did not actually take place. However, after the other changes, survey results showed that water quality still did not meet standards for water contact sports (Berkeley, 1969).

On September 10, 1969, the second, more extensive fish kill occurred. A body count indicated over 400 striped bass and several hundred smelt dead in the Park (CDFG, 1969). Dissolved oxygen (DO) levels in the lake were found to be 0.0 mg/L. It was concluded that lack of oxygen had killed the fish, and that overgrowth of duckweed and algae had to be eliminated (Berkeley, 1969). To combat the weed problem, a mechanical weed harvester was purchased for $30,000. To curb runoff pollution, an interceptor sewer was installed on the east side at a cost of $100,000. It was completed in 1971, reducing industrial dumping into the lagoon (Cardwell, 1972).

At this time, the maintenance practice was to run the mechanical harvester daily for three months during the summer. Also, the tide gates were cleaned in the spring after the rains and in the fall before the rains. The harvester purchased by the City was designed for freshwater use. It thus corroded and ceased functioning over five years ago (Raxter, 1988, pers. comm.).

On December 18, 1981, Colgate-Palmolive ceased production, thus ending its practice of pumping out almost 800,000 gallons per day of Aquatic Park water. This water had been discharged to the Potter street outfall and into the Bay on a regular basis. This was a significant drain on the Park, and at times the effluent had to be rerouted back into the Park to keep water levels up (RWQCB, 1979).

Current Conditions and Maintenance Practices: From 1982 to the present, no complaints of algal blooms have been made. These complaints would normally be made by water skiers, as the plant life can interfere with their boats. Skiers use the Park between May 1 and November

1 (Spencer, 1989, Pers. Comm.). Park maintenance was limited to cleaning the tide gates twice a year. The last time they were actually cleaned was in 1986. This was a partial cleaning, as they could not get the machines through the clogged gates any longer. The two 18-inch pipes which connect lagoon N to lagoon C have not been cleaned for over five years, during which time they have been clogged. Currently, storm drains run into the east side of the lagoon from Allston Way, Bancroft Way, and Channing Way (Raxter, 1989, pers. comm.).

Water Quality Parameters Tested: I tested the water for temperature, pH, conductivity, dissolved oxygen, ammonia nitrogen, organic nitrogen, orthophosphates, and turbidity .

Water temperature is affected by solar radiation and the temperature of inflow. It affects the solubility of other parameters and is utilized in the determination of saturation levels of dissolved oxygen in water. RWQCB standards for temperature state that incoming waters may not increase the temperature of the receiving waters by more than 2.8°C (RWQCB, 1986).

The measure of the concentration of hydrogen ions in water is called pH. Aquatic life is sensitive to changes in pH. This is because the pH affects the toxicity of certain compounds to aquatic life. The pH standard for marine life is that it may range from 6.5 to 8.5 (RWQCB, 1986).

Conductivity is a numerical expression of the ability of an aqueous solution to carry an electrical current. It depends on the concentration and valences of dissolved ionic solids (APHA, 1985). Depending on temperature, seawater has a specific conductance ranging from 30 to 70 mmhos/cm (Altamirano, 1983).

Salinity is measured in parts per thousand (‰) and is proportional to conductivity. This proportion depends on the temperature of the solution and the characteristics of the dissolved ionic solids therein. Aquatic life, especially estuarine wildlife, is sensitive to salinity, which can define the habitat range (Kennish, 1986). Salinity standards state that "controllable water quality factors shall not increase the total dissolved solids or salinity of waters of the State so as to adversely affect beneficial uses, particularly fish migration and estuarine habitat" (RWQCB, 1986).

Dissolved oxygen (DO) levels are one of the most important measures of water quality. Without an adequate amount of free DO, estuaries are uninhabitable by most aquatic life (Vesilind and Pierce, 1983). Standards for DO are set at a minimum of 5 mg/L (RWQCB, 1986) and a maximum not to exceed 110 percent of the saturation value for oxygen at the existing temperature, atmospheric pressure, and salinity (EPA, 1986). Saturation is determined by temperature, air pressure, and sea level. For Aquatic Park, saturation at 13°C is 10.52 mg/L, at 14°C it is 10.29 mg/L, and at 15°C it is 10.07 mg/L.

Ammonia is acutely toxic to some fish at concentrations as low as 0.53 mg/L; hence the RWQCB sets standards at a maximum of 0.16 mg/L in the Central Bay (RWQCB, 1986).

Nutrient elements, such as phosphorus and nitrogen, are usually found in much higher concentrations in freshwater than sea water. They can be biostimulatory in that they can cause excess primary production of plant growth. The enrichment of Aquatic Park by nutrients would mostly be from land drainage, and their presence would probably be felt after heavy rains. In estuaries, nitrogen, more so than phosphorus, tends to be the chief limiting element to primary production (Kennish, 1986). Bay standards state that "waters shall not contain biostimulatory substances in concentrations that promote aquatic growths to the extent that such growths cause nuisance or adversely affect beneficial uses" (RWQCB, 1986).

Organic nitrogen (amino acids, peptides, and urea) may be useful nutrient sources for autotrophic growth. Organic nitrogen in the presence of ammonia indicates recent pollution (Vesilind and Pierce, 1983). Clean drinking water should not have organic nitrogen in excess of 10 ug/L. Waste water can be as concentrated as 10 mg/L (APHA, 1985).

Orthophosphates are the form of phosphate applied as fertilizers. The concentration of dissolved phosphates in estuarine waters seems to be related to sediment adsorption processes. A lack of phosphates may limit growth, but the minimum necessary concentration is unknown. EPA standards state that maximum concentrations are not to exceed 25 ug/L (EPA, 1986).

Turbidity is caused by silt that is brought in by runoff, wave action and wind that carry particles from the Bay and land. Turbidity is an expression of the optical property that causes light to be scattered and absorbed rather than transmitted. It is measured in Jackson Turbidity Units (JTU). For estuarine waters, there should not be enough turbidity that sunlight is unable to penetrate to the lower levels. Changes in turbidity are the key factor here. Bay standards state that increases from normal background light penetration or turbidity relatable to waste discharge shall not be greater than 10 percent in areas of 10 JTUs or more (RWQCB, 1986).

Water Quality Methodology

On the first test date (11/22/88), samples were collected at Sites 1-7 (Figure 1), one from the southern lagoon S (Site 1), two from the central lagoon C (Sites 2 and 3), and four from the northern lagoon N (Sites 4-7). In lagoon N, sample 4 was taken close to the dike which separates lagoon N from lagoon C; sample 5 was taken at the mouth of a small spring on the east shore of the Park; sample 6 was taken next to the tide gates on the west shore; and sample 7 was taken at the far north of the Park in the vicinity of a storm drain outlet (Figure 1). On the second test date (2/22/88), samples were taken only at Sites 2-7. I was unable to get a sample at Site 1 due to low tide which exposed an extensive mud flat which I could not wade through to collect a sample.

The first samples were gathered in the morning forty minutes after high tide on November 22, 1988. I started at Site 7, then did 6, then 1 to 5 in that order. The process took an hour and forty-six minutes. This was after the first significant rainfall of the month, 0.78 inches. It was raining when I gathered samples. The second samples were gathered in the afternoon on an ebb tide on February 22, 1989. I started gathering samples at 4:50 pm, and finished at 6:30 pm. Low tide, including the correction for the difference between the Golden Gate and Berkeley, was at 6:57 pm (SF Chronicle, 1989). The order of sample gathering was Site 7, then 2 to 6. The cumulative rainfall of the season at this time was 11.08 inches. This was a drier period than the former, as the only precipitation had occurred four days previously and amounted to 0.18 inches (U.S. Weather Service, 1989).

Samples were collected in one-gallon plastic milk jugs, which were previously washed with boiling water, then rinsed twice with the sample water before collecting. They were immersed about one foot below the surface before being filled and capped. All field and lab equipment were supplied by Bruce Jacobson at the Sanitary Engineering laboratory in Davis Hall.

Parameters tested in the field were temperature, pH, conductivity, salinity, and dissolved oxygen, in that order. The temperature was read from a standard mercury thermometer. The pH was measured with a "pocket pH meter". Conductivity was measured with a YSI model 131 conductivity meter. DO was measured with a DO meter which needed to be calibrated according to temperature and salinity. Salinity was extrapolated from a chart which required the temperature and conductivity (Cox, 1965). I made a graph from this chart and visually located the salinity corresponding to the measured conductivity. This method is not the method of choice, but rather a method of convenience used to get a general sense of the salinity. General observations of surface conditions were also made at the time of sample collection.

Kjeldahl total nitrogen and Kjeldahl ammonia were tested in the laboratory. Organic nitrogen is the difference between these. Orthophosphates were measured by the stannous chloride method and colorimetric determination. Turbidity was measured using a Fisher Turbidimeter DRT-1000. All these tests were in accordance with standard methods (APHA, 1985).

Results

Temperatures ranged from 13.0 to 14.2°C and averaged 13.4°C on the first test date (11/22/88) (Table 1). On the second date (2/22/89), temperatures ranged from 14.0 to 15.2 °C and averaged 14.6°C (Table 2).

On the first test date (11/22/88), pH was 7.7 at all Sites in lagoon N and slightly higher, 7.9 to 8.0 in lagoon C and lagoon S (Table 1). In February, there was a reversal, as lagoon C had a pH of 7.7, whereas lagoon N increased to an average of 8.2 (Table 2).

The conductivity decreased over the rainy season, but was always higher in lagoon C than in lagoon N. On the first test date lagoon C averaged 35.4, which is very similar to sea water. Lagoon N had various readings, ranging from a low of 19.4 to a high of 32.7 mmho/cm. These levels classify it at the lower threshhold of sea water, except for Site 7. As this is the Site of storm drain overflows, it is clear that during the heavy rain, "fresh water" from the City makes its presence felt (Table 1). In February, when there had not been rain for some time before testing, the conductivity in lagoon N was more uniform, indicating mixing of the "fresh water" from previous rains. In February conductivity was no higher than 29.9 mmho/cm in lagoon C, and ranged from 22.3 to 23.3 mmho/cm in lagoon N (Table 2).

In November, the salinity ranged from 14.5‰ at Site 7 to 30‰ at Site 2. Salinity was highest in lagoon C, averaging 29.7‰. The overall lowest measures were in lagoon N (Table 1). In February, salinity was lower, but more uniform. It ranged from 17.5‰ at Sites 5 and 6, to 23.5‰ at Site 3 (Table 2).

In November, DO ranged from 7.3 to 12.5 mg/L and was above saturation at Site 1 and supersaturated at Site 7 (Table 1). In February, DO ranged from 10.3 to 12.6 mg/L and was above saturation at all Sites and supersaturated at Sites 4 and 5 (Table 2). In November, DO was considerably lower in lagoon C (7.3 and 8.8 mg/L) than in lagoon N, where it ranged from 9.9 to 11.0 mg/L. In February, DO levels averaged 11.6 in lagoon C and 11.5 in lagoon N.

In November, organic nitrogen ranged from unmeasurable (zero) at Site 7 and 0.45 mg/L at Site 1 to a high of 2.5 to 3.0 mg/L in lagoon C (Tables 1 and 2). In the rest of lagoon N, organic nitrogen ranged from 1.3 to 1.6 mg/L. In February, measurements were lower overall, and an exceptional drop in concentration took place in lagoon C, where levels dipped below 0.5 mg/L. In lagoon N, organic nitrogen averaged around 1.0 mg/L except at Site 7, where very low levels were detected. This is very interesting, because the source of nutrient elements is urban runoff, and Site 7 is at the mouth of a prominent point of runoff into lagoon N. However, Site 7 is consistently low in detectable organic nitrogen compared to the rest of the lagoon.

Site	Temp. °C	pH	Conductivity mmho/cm	Salinity o/oo	DO mg/L	Organic N mg/L	Ortho P ug/L	Turbidity JTU
1	13.5	7.9	32.7	27.0	12.5	0.45	160	12.0
2	13.0	8.0	35.8	30.0	7.3	2.48	40	8.1
3	13.5	7.9	35.1	29.5	8.8	2.97	40	8.3
4	13.0	7.7	29.6	24.5	9.9	1.57	70	7.3
5	13.5	7.7	32.7	27.0	9.9	1.33	30	6.5
6	13.2	7.7	32.1	26.5	10.2	1.26	70	4.9
7	14.2	7.7	19.4	14.5	11.0	0	160	25.0

Table 1. Temperature, pH, conductivity, salinity, DO, organic nitrogen, orthophosphate, and turbidity at Sites 1-7, for November 22, 1988. Horizontal lines divide the separate lagoons.

Site	Temp. °C	pH	Conductivity mmho/cm	Salinity o/oo	DO mg/L	Organic N mg/L	Ortho P ug/L	Turbidity JTU
2	15.2	7.7	29.5	23.0	11.7	0.33	270	7.4
3	15.0	7.7	29.9	23.5	11.5	0.26	210	7.2
4	15.0	8.1	23.3	18.0	12.6	1.06	30	4.0
5	14.5	8.2	22.9	17.5	12.1	1.06	50	4.2
6	14.0	8.2	22.3	17.5	11.1	0.92	50	3.5
7	14.0	8.3	23.2	18.0	10.3	0.08	30	3.2

Table 2. Temperature, pH, conductivity, salinity, DO, organic nitrogen, orthophosphate, and turbidity at Sites 2-7, for February 22, 1989. Site 1 was not sampled on this date. Horizontal lines divide the separate lagoons.

In November, orthophosphates ranged from 30 to 160 ug/L, but most Sites were at the lower range (Table 1). In February, measurements in lagoon N, including Site 7 averaged 40 ug/L. However, orthophosphates in lagoon C were very high, 210 and 270 ug/L (Table 2). These levels greatly exceed standards.

Turbidity was relatively consistent at Sites 2 and 3 in lagoon C on each measurement date (Tables 1 and 2). It decreased from an average of 8.2 JTUs in November to an average of 7.3 JTUs in February. Sites 4 to 7 in lagoon N had highly variable turbidity in November, with an exceptionally high reading of 25 JTUs at Site 7, and a range from 4.9 to 7.3 JTUs at Sites 4 to 6. Site 7 accumulated the most debris. With the exception of Site 7, turbidity was lower in lagoon N than in lagoons C or S. In February, without the activity of turbulent rain and drainpipe effluent, turbidity at Site 7 was lower, and average turbidity was 3.7 JTUs in lagoon N.

General observation of the lagoon incidates that debris accumulates at Site 7, and that there is consistently more algae and green aquatic plant growth in lagoon C. All the lagoon waters tended to be green, and visibility was only up to two feet of depth on both test dates. In February, oil was observed on the surface of lagoon N. No ammonia was detected on either test date.

Discussion

With the exception of very high orthophosphate and DO readings, and oil observed on the surface of lagoon N, values for all parameters tested were within RWQCB and EPA standards.

Much of my data demonstrate the autonomy of the lagoons C and N. For example, conductivity was always higher in lagoon C than N. This indicates that compared to lagoon N, lagoon C has higher evaporation and lower dilution rates. The independent reversal in pH levels is another example of lagoon autonomy. There is reduced circulation between the lagoons, and particles which enter lagoon C tend to remain there as evidenced by higher turbidity. The greatest growth of algae and weeds was observed in lagoon C. Since a concentration of different factors, such as pollutants or biostimulatory nutrients, can lead to damage to aquatic life and an unpleasant environment, improving circulation between lagoons C and N would be very beneficial, especially to lagoon C.

The salinity levels in the Park were lower in February than in November. This is probably because accumulation of rainfall dilutes the Park water. It would be very interesting to monitor the seasonal fluctuation of salinity and to study the kinds of wildlife that would be best suited to the ranges and fluctuations of salinity that the Park exhibits.

In my study as well as other studies (Altamirano, 1983), DO tends to be unlimiting in the spring. Several of the sites I sampled were supersaturated; thus they exceeded EPA standards. In November, Site 1 was supersaturated, as were Sites 4 and 5 in February. This could be due to excess agitation of the water in sample gathering, inadequate calibration of the DO meter, or excess oxygen production by plant life. It would be beneficial to continue monitoring the DO at Aquatic Park to measure the daily and seasonal fluctuations.

Organic nitrogen and phosphates have proved to be a most interesting part of my study. In lagoon C, on the first test date, organic nitrogen is very abundant, whereas three months later it is below the level of lagoon N. The exact opposite is true of phosphates. The very high measurements at Site 7 in November indicate that runoff was the source of orthophosphates. However, there is an abundance of phosphates when there is a dearth of organic nitrogen and vice versa. It is difficult to say why this occurred. If they resulted simply from urban runoff, one might expect a similarity in the levels, unless there are different application times of fertilizers by urban gardeners. Additionally, since there is no direct discharge of drain pipes into lagoon C, it would be interesting to find out what its source of nutrients was. By virtue of these data alone, one can see that analysis of even a small lagoon system requires regular monitoring. It is not clear whether the organic nitrogen or orthophosphates stimulated algal growth. In order to ascertain this possibility, chlorophyll concentrations could have been measured, and should be monitored in the future.

State standards are flexible as to the acceptable level of turbidity (normal levels are not defined). Therefore, it is impossible to say if the turbidity encountered is an acceptable level for Aquatic Park. From an aesthetic perspective, the water appears green and murky, certainly undesirable for swimming in, as opening one's eyes or mouth would be unpleasant. It would be beneficial to study acceptable levels of turbidity for aquatic life, and also the effect of aquatic plants and animals on siltation and turbidity.

From past studies, it is apparent that there are many things to take into consideration when assessing Aquatic Park water quality. Historically, oil and grease have been a problem at Aquatic Park. The City of Berkeley found the sediments high in oil and grease (Beers and Wistrom, 1969), and Altamirano (1983) reported surface oil in lagoon N. Pollution from urban and industrial sources has been discharged into Aquatic Park over the years. Before they ceased production, Colgate-Palmolive discharged organic materials and phosphates into the Park from two outfalls. An 8-inch pipe near Cutter Laboratories discharged concentrated pollutants at irregular intervals (Grove, 1969). Mercury levels exceeded standards in 1983 (Altamirano, 1983). Due to its history, it is impossible to ascertain what has accumulated, or could pose a hazard without testing the sediment in the Park.

A better indication of water quality for human and wildlife use is a coliform count. Previous studies have shown that during heavy rainfall, there is a strong influx of coliforms, which diminishes as the rainy season continues (Betts, 1983). After one particular rainy period, there was evidence of human fecal contamination of the Park. During dry periods, the coliform level is lower and constant (Betts, 1983). In summer, coliform levels have been acceptable (Feldman, 1989, pers. comm.).

Conclusion

Water quality at Aquatic Park is not ideal. My studies of just a few chemical and physical parameters indicate that the quality could be improved. In order to do this, it would be beneficial to know much more about the Park. In the several months that I have spent researching Aquatic Park, I am surprised at how many more questions I have than when I began. First of all, a much more thorough look at the lagoon quality, including sediments, circulation, and biological life, would be beneficial. A thorough study of the lagoon sediments for health hazards would be valuable in laying to rest any fears of accumulated pollutants, and working towards a truly clean Park. The quality and sources of incoming water, including the "springs" emanating from the industrial region on the east side of the Park, should be regularly monitored. The mechanical aspects of circulation must be more consistently maintained. The tide gates should be cleaned, as well as the culverts that connect lagoons C and N. The kinds of aquatic life which would find the Park suitable should be investigated and encouraged. The Park is a good Site for experimentation in biological controls, such as growing aquatic plants for the purpose of filtration. It should be a goal to restore natural vegetation and restructure the lagoons to enhance the quality of the lagoons with respect to wildlife (see Jacobs paper, this publication). The health of wildlife can be a good indication of water quality (for example, fish kills) and the existence of wildlife can be very rewarding to a community. In short, it would be worthwhile to try to improve the water quality and make it more consistent using biological means in order to have a clean, beautiful, natural area in the City of Berkeley.

References

Altamirano, C., 1983. Water Quality in Aquatic Park: chemical and physical parameters affecting recreation and wildlife. In *Berkeley Water: Issues and Resources*; D. Sloan and S. Stine, eds.; U.C. Berkeley Environmental Sciences Senior Seminar report, Berkeley, CA, pp. 135 - 145.

American Public Health Association (APHA), 1985. *Standard Methods for the Examination of Water and Wastewater*, 16th Edition, Washington, DC, American Public Health Association, 1268 pp.

Beers, G.D and T.V. Wistrom, 1969. *A Report on Preliminary Investigations of Waters and Sediments in Aquatic Park Lagoon;* Unpublished report by Engineering-Science Inc. for the City of Berkeley, CA, 52 pp.

Berkeley, City of, 1945. *Report on Aquatic Park;* Parks and Recreation Department, 4pp (Available at Marina Office).

_____, 1969, Department of Environmental Health Aquatic Park Files of 1969-70, Berkeley, California, npp.

Betts, I., 1983. Water quality at Aquatic Park: biological parameters. In *Berkeley Water: Issues and Resources;* D. Sloan and S. Stine, eds.; U.C. Berkeley Environmenta Sciences Senior Seminar report, Berkeley, CA, pp. 147-154.

Cardwell, M., 1972. Tenth Anniversary Letter- Friends of Aquatic Park: Berkeley, CA.

California Department of Fish and Game (CDFG), 1969. *Initial Report of Fish and Wildlife Loss, Aquatic Park, Berkeley.* Resource Agency of California, Department of Fish and Game, 3pp.

Cox, R. A., 1965. The physical properties of sea water. In *Chemical Oceanography, Vol. 1*; Riley, J.P. and G. Skirrow, eds., London, Academic Press, pp 73-120.

Cresswell, C.W., 1938. *Report on the Aquatic Park,* Berkeley, CA, 4pp (Available at Marina Office).

Environmental Protection Agency (EPA), 1986. *Quality Criteria for Water, 1986.* United States Environmental Protection Agency, Washington, DC, EPA 440/5-86-001.

Erickson, P. and B. Ernst, J. Huettl, T. McKeag, E. Owens, P. Wang, J. Webber, 1986. *Aquatic Park: Preliminary Master Planning Report.* Unpublished report by students of the University of California at Berkeley, College of Environmental Design, 55pp.

Feldman, L., 1989. Supervisor, Regional Water Quality Control Board, California. Personal Communication, 2/23/89.

Ferlin, C. L., 1983. History and development of Aquatic Park. In *Berkeley Water: Issues and Resources;* D. Sloan and S. Stine, eds., U.C. Berkeley Environmental Sciences Senior Seminar report, Berkeley, CA,pp. 127-133.

Grove, J., 1969. *Study of conditions in Aquatic Park at the request of the Sierra Club.* Unpublished report for the Sierra Club, Oakland, California, 12 pp.

Kennish, M.J., 1986. *Ecology of Estuaries Vol 1, Physical and Chemical Aspects;* Boca Raton, Florida, CRC Press, Inc., 254pp.

Raxter, D., 1988, Senior Supervisor, Public works Maintenance, City of Berkeley. Personal Communication, 11/18/88.

_____, 1989, Senior Supervisor, Public works Maintenance, City of Berkeley. Personal Communication, 5/2/89.

Regional Water Quality Control Board (RWQCB), 1979. File #79-156; Colgate-Palmolive, Oakland, California.

_____, 1986. *Water Quality Control Plan, San Francisco Bay Basin Amendments,* Oakland, California, 116 pp.

Spencer, V., 1989, Manager of Health Protection, City of Berkeley Environmental Health Department; Personal Communication, 2/16/88.

U.S. National Weather Service, 1989. Station #04-0693-4, University of California at Berkeley Geography Department, US Department of Commerce, National Oceanic and Atmospheric Administration.

Vesilind, P.A., and J.J. Pierce, 1983. *Environmental Pollution and Control, 2nd edition*, Stoneham, MA, Butterworth Publishers, 393 pp.