MOSES LAKE DILUTION PROJECT

SUMMARY REPORT

APRIL 1984

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prepared for the

Moses Lake Irrigation and Rehabilitation District

April 1984

by

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Special acknowledgment is made to Dr. Eugene B. Welch of the University of Washington Department of Civil Engineering for his contributions to this work. Dr. Welch presented a technical paper at an American Water Resources Association meeting in Spokane, Washington, November 1983, entitled "Addition of Dilution Water to improve Moses Lake Quality" which provides a summary of technical data covering six years of study and effects of the Moses Lake Dilution Program.

Funding for this project was provided by the U.S. Environmental Protection Agency, Washington State Department of Ecology, and the Moses Lake Irrigation and Rehabilitation District. Water releases for the dilution project have been provided by the U.S. Bureau of Reclamation, Columbia Basin Project.

Front photograph is a scene of the Pelican Horn area of Moses Lake. Photo taken by Jim Hertz.

INTRODUCTION

The Moses Lake Dilution Project represents six years of concerted effort to improve water quality in an excessively eutrophic lake. Moses Lake is a large, shallow lake centrally located in the State of Washington. The lake is regulated as part of the Columbia Basin Project which supplies water stored behind Grand Coulee Dam to over 500,000 acres of farmland. Moses Lake itself serves as a supply route for water passing from the East Low Canal, north of Moses Lake, to the Potholes Reservoir, to the south, providing water to the lower part of the irrigation project. See Figure 1, Location Map.

Moses Lake has experienced extensive blue-green algae blooms for over two decades, resulting in diminished recreational use of the lake. The lake has been studied since the early 1960s to determine the source of the noxious blooms and to develop algae control mechanisms. During the late 1970s a restoration program began which diluted a portion of the lake with low-nutrient Columbia River water during the late spring and summer. The success of the dilution program in reducing localized algae blooms resulted in the construction of a permanent dilution facility in 1982 to further distribute dilution water within Moses Lake. This report summarizes the dilution project and its accomplishments.

VIEW OF MOSES LAKE with Pelican Horn in foreground.

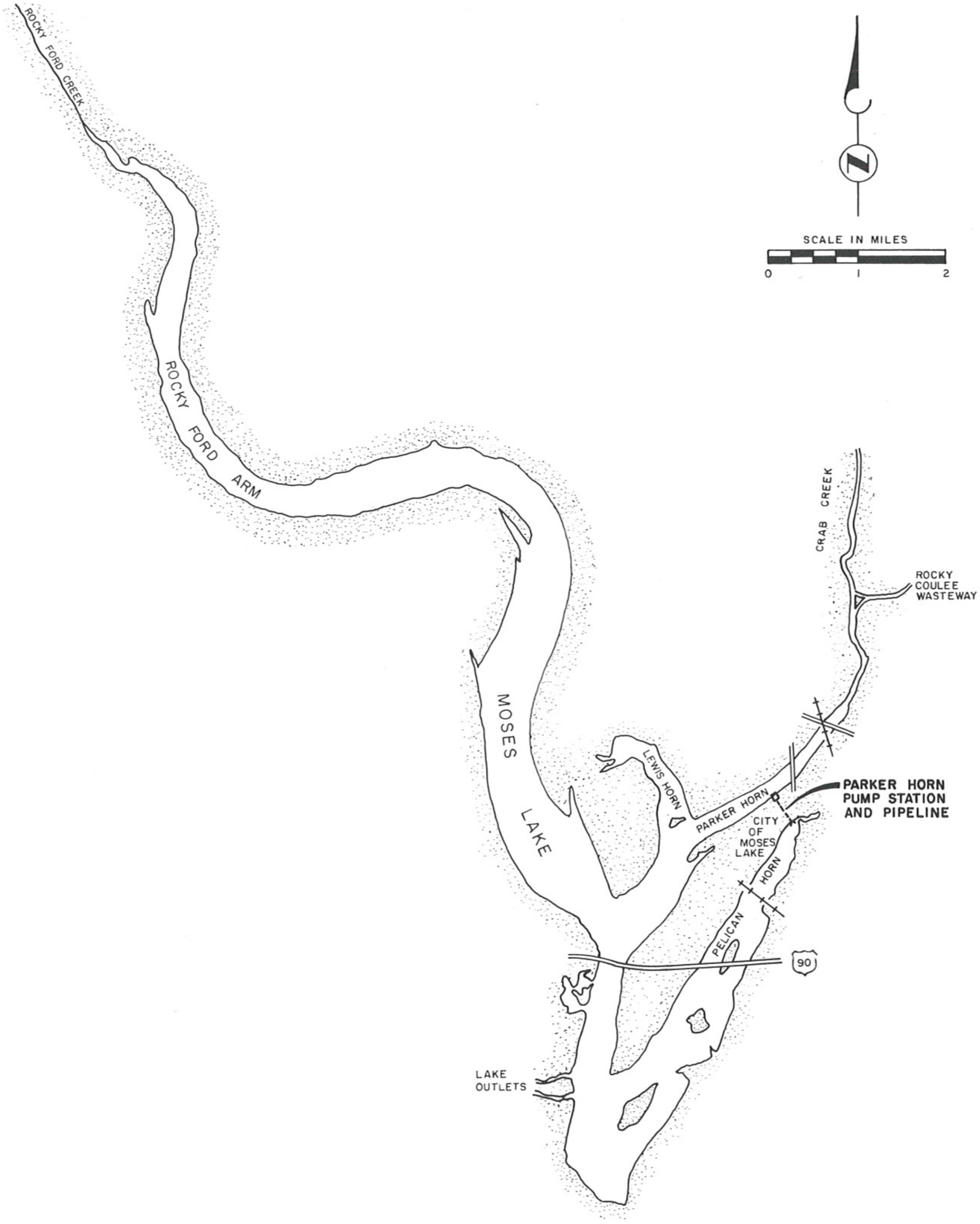


Figure 1. Moses Lake Location Map

THE LAKE AND ITS WATERSHED

Moses lake was formed years ago by drifting sand damming Crab Creek. The lake had no surface outlet until 1904 when flood waters scoured a channel and lowered the lake level by eight to ten feet. A dam constructed in 1909 failed and was not rebuilt until 1929, when the Moses Lake Irrigation District constructed an outlet works, restoring the lake to its earlier elevation of 1,046 feet. A second outflow works was constructed by the U.S. Bureau of Reclamation in 1963. Outlet structures control lake level between 1,041 and 1,048 feet. Lake level is currently maintained at about 1,046 feet through the cooperative efforts of the Irrigation District and the Bureau of Reclamation.

The lake is segmented into three major arms or horns; the main arm extends north and is fed by Rocky Ford Creek, the southern portion includes Parker and Pelican Horns which are separated by a peninsula which includes much of the commercial district of the City of Moses Lake. Parker Horn is fed by Crab Creek. A smaller embayment, called Lewis Horn, is connected with Parker Horn, see Location Map, Figure 1. Physical characteristics of Moses Lake and various segments of the lake are shown in Table 1.

Table 1. Physical Characteristics of Moses Lake, Washington[a]

Area	6,800 acres	2,753 hectares
Maximum depth	38 feet	11.6 meters
Mean depth	18.5 feet	5.6 meters
Volume	126,000 acre-feet	153.7×10^6 m^3
Total length	20.5 miles	32.8 km
Parker Horn		
Mean depth	12.6 feet	3.8 meters
Area	758 acres	307 hectares
Volume	9,520 acre-feet	11.6×10^6 m^3
Pelican Horn		
Mean depth	15.6 feet	4.8 meters
Area	1,600 acres	648 hectares
Volume	25,000 acre-feet	30.5×10^6 m^3

[a]Sylvester and Oglesby, 1964, based on a lake water surface elevation of 1946.

The dominant fish in Moses Lake is the European carp (*Cyprinus carpio*). Despite its size and value as food in other parts of the world, most local residents regard carp as a nuisance, undesirable as a game fish, and damaging to other more desirable species. Carp has been fished commercially from the lake. Of more interest to anglers are the large numbers of rainbow trout, largemouth black bass, white crappie, yellow perch, and bluegill. Fishing is open the year round. South of Moses Lake, Potholes Reservoir and the many small lakes in the surrounding area are well known to sport fishermen. Walleye to eight pounds, bass to four, and trout to six pounds, have been reported. Moses Lake is well known among sportsmen for its bass fishing and bass tournaments are held here each year.

Moses Lake is used extensively for recreational purposes. Boaters are served by two marinas located on the lake and by a number of public launch facilities. Swimming is popular during the late spring and summer at many locations about the lake. Public swimming beaches include Cascade Valley Park on Lewis Horn, Montlake Park on Pelican Horn, and Moses Lake State Park and Airman's Beach on the main arm. Moses Lake also is the site of an annual water ski tournament. Many homes and numerous business establishments have been designed to take maximum advantage of lake views and waterfront. Many of the private homes on the waterfront have docks, bulkheads, or other shoreline structures constructed for swimming, fishing, and boat moorage.

SUMMER ACTIVITIES at the Moses Lake State Park in Parker Horn

The total watershed encompasses approximately 2,450 square miles (6,255 square kilometers); Crab Creek drains about 84 percent of the watershed. Crab Creek flows vary widely; flows monitored by the U.S. Geological Survey have normally averaged between 50 and 150 cfs during the past twenty years. Higher flows occur during periods when dilution water is released into Crab Creek from the East Low Canal. Rocky Ford Creek regularly contributes 65 to 90 cfs largely from springs within this small watershed.

The major urban center in the watershed is the City of Moses Lake (population 10,300). The City and surrounding urban fringe account for a population of approximately 20,000 people. The urban centers of

Ephrata-Soap Lake (population 10,400) which lie outside the watershed contribute to the underground flow tributary to Moses Lake. Although much of the urban and all the rural population is unsewered, there are sewer systems in Moses Lake, Ephrata, and Soap Lake.

WINTER RECREATION on Moses Lake's Pelican Horn

The Moses Lake area has a semi-arid climate with four distinct seasons. Extreme temperatures commonly exceed 100 degrees F in summer and reach below zero degrees F in winter. The difference between daily high and low temperatures varies from as little as 15 degrees F in January to as much as 40 degrees F in July. The frost-free season is about 150 days beginning in late April. Precipitation is about 8 inches annually, most of which occurs as rain or snow in the period November through March. Evaporation is quite high, particularly during the warm summer months. Average annual evaporation values are between 58 and 60 inches.

Much of the land in the Crab Creek watershed is devoted to agriculture. There are three basic types of agriculture: rangeland, irrigated cropping, and dryland agriculture. Irrigated cropping (sprinkler and flood application) predominates in the lower watershed, while dryland wheat farming and cattle range are the major agricultural activities in northern Grant County and Lincoln County. Dry crop and rangeland contribute solids and nutrients to the system during runoff, which occurs primarily in the late winter and early spring following snowmelt.

Coarse shallow soils predominant in the Crab Creek and Rocky Ford Creek watersheds, particularly in southern Grant County, allow significant percolation of precipitation. Studies conducted for the Moses Lake Irrigation and Rehabilitation District in 1982-83 have shown that local groundwater flow and quality is affected by water percolating from agricultural lands.

THE PROBLEM AND ITS CAUSES

Over production of algae is the primary water quality problem in Moses Lake. Nuisance levels of blue-green algae form unsightly floating mats in the summer recreation season. These algal scums also produce unpleasant odors and have been associated with toxicity to animals drinking at the lake shore. Aquatic weed growth is also a problem in some shoreline areas.

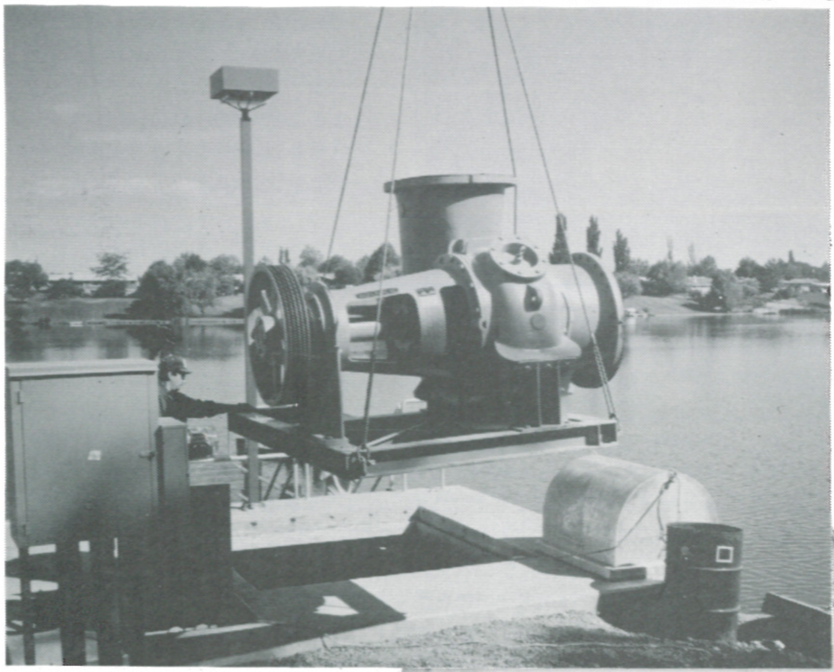
BLUE-GREEN ALGAE tend to form unsightly surface scums

Nitrogen and phosphorus are the major nutrients causing over-fertilization of Moses Lake. The principal sources of enrichment to the lake include irrigation return waters via the principal surface streams and groundwater, municipal sewage effluent and septic tank leachate, and recycling from bottom sediments through sediment-water interchange induced by wind and carp activity. Sewage effluent from the City of Moses Lake ceased to be discharged to Moses Lake during the spring of 1984.

Nitrogen is known to limit growth rate during the summer according to studies by Dr. Eugene Welch of the University of Washington Department of Civil Engineering. However, phosphorus is also important because the principal bloom former, the blue-green algae (Aphanizomen flos-aquae) has the ability to fix nitrogen from the atmosphere. The flow-weighted average nitrate concentration flowing into the lake during spring-summer has been found to be a good predictor of summer average algae biomass. During 1980 and 1981; however, soluble phosphate concentration in lake inflow declined following the Mount St. Helen's ashfall, making phosphorus the limiting nutrient for those years.

DESIGN AND CONSTRUCTION OF DILUTION FACILITIES

Results of the 1977 dilution demonstrations stimulated funding of facilities to transfer diluted lake water from Parker Horn into nearby Pelican Horn. A low head pumping plant was designed with a capacity of 50 cfs to transfer dilution water approximately 2,800 feet across the City of Moses Lake for discharge at a shoreline park located at the upper end of Pelican Horn. This project was built at a cost of approximately $875,000 and put in operation during the summer of 1982. Grant funds were provided to the Moses Lake Irrigation and Rehabilitation District by the Department of Ecology and the Environmental Protection Agency. An additional dilution project was also evaluated for the main arm of the lake via Rocky Ford Creek; however, this project was not feasible. Grant funds originally dedicated for this project have since been used to assist in removing the City of Moses Lake's sewage effluent from Pelican Horn and to fund evaluations of nutrient control approaches in the watershed. These watershed studies include on-farm demonstrations of improved water and fertilizer management techniques and other source control measures. These source control studies are continuing during 1984.

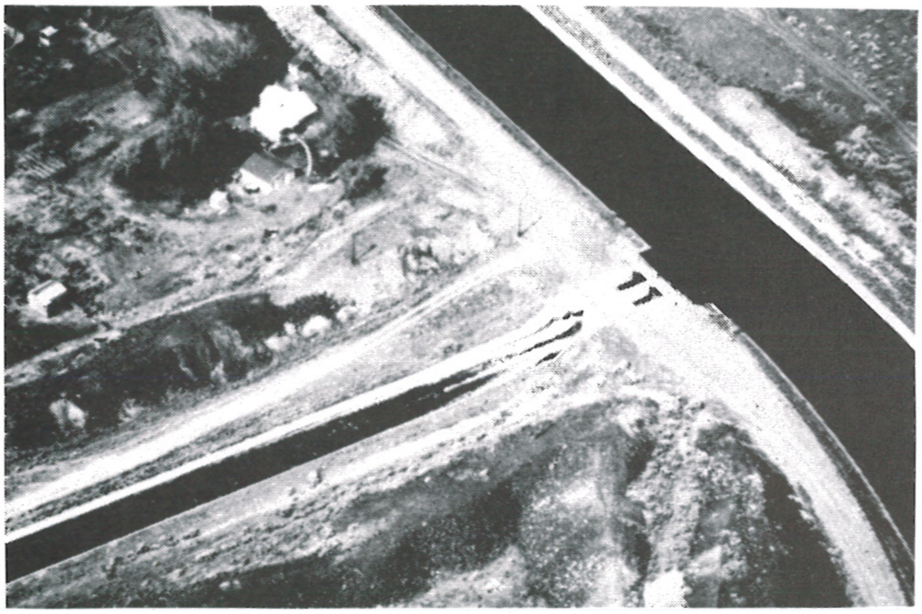


PUMP BEING installed in pump station

PARKER HORN PUMP STATION under construction

1977 DILUTION DEMONSTRATIONS

A demonstration project was planned for full scale testing in the spring and summer of 1977 using Parker Horn as the major test area. Arrangements for delivery of dilution water were made with the U.S. Bureau of Reclamation Columbia Basin Project Office in Ephrata. Ultimately some 155,000 acre-feet were released with nearly 110,000 acre-feet from March 18 through May 9, approximately 10,000 acre-feet from May 24 through June 7, and a third release of 35,000 acre-feet from August 13 through September 12. Dilution water was provided from the U.S. Bureau of Reclamation's East Low Canal via the Rocky Coulee Wasteway which flows into Crab Creek 1-1/2 miles upstream of Parker Horn.

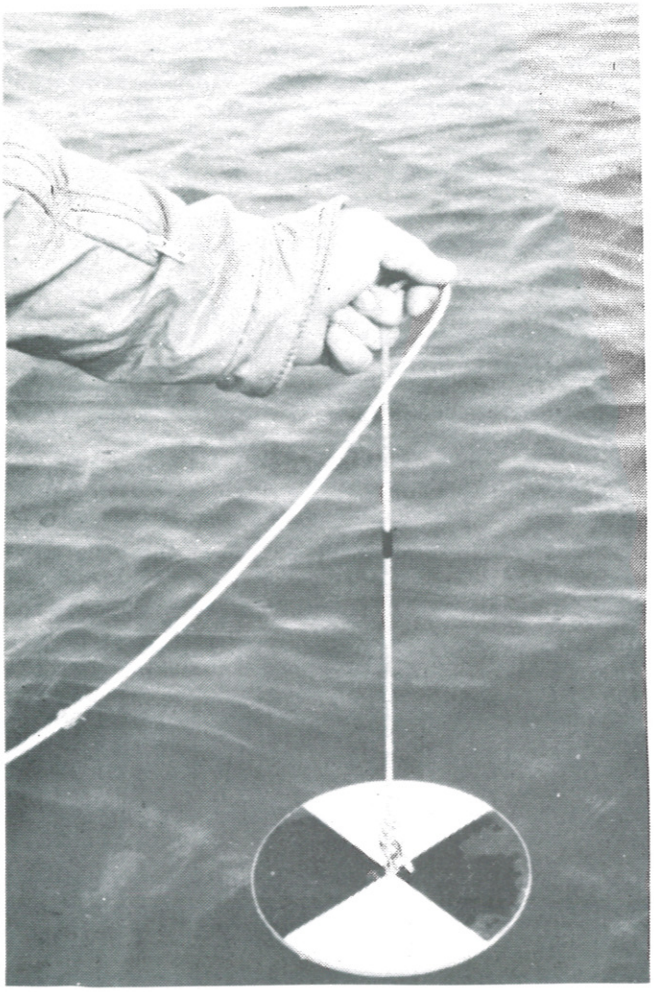


EAST LOW CANAL outlet structure is dilution water release point into Rocky Coulee Wasteway

The demonstration project focused on water quality measurements before, during, and after each canal release period to provide data which could be compared with 1969 conditions as measured by the University of Washington. In addition, the project enabled comparisons to be made for the differing conditions which were created during 1977 at various locations within Moses Lake and in downstream areas, particularly Potholes Reservoir. Past concern over aquatic growths in the Potholes area and in downstream irrigation canals urged caution with respect to potential water quality changes which could result from a Moses Lake "dilution" project and thereby affect downstream irrigation operations.

The 1977 Sampling Program

The 1977 sampling program for the Moses Lake demonstration project included a total of 17 stations, 8 in Moses Lake itself, 2 in Potholes Reservoir, and the remaining 7 in adjacent streams and



SECCHI DISC being lowered into lake to measure water transparency

wasteways. Sampling was conducted weekly or biweekly depending upon station during the March-through-September sampling period. In addition to measurement of standard water quality parameters, samples were analyzed for nutrients and planktonic algae concentrations.

Water Quality Goals

Water quality goals were established. A phosphorus goal was established based on earlier work by Welch as 50 ug/l, a level believed necessary to control algal growth below 20 ug/l chlorophyll; thus the phosphorus and chlorophyll a goals are interrelated. Similarly, a water clarity goal was established which is in part dependent on algal growth levels (i.e., chlorophyll) as well as on the nature of the growths (e.g., diatoms vs. floating blue-green algae forms). The transparency goal, 4 feet, as measured by Secchi disc, is also tied to swimming safety; the transparency and chlorophyll goals are also a gross measure of aesthetic conditions in the lake.

1977 DILUTION DEMONSTRATION RESULTS

Generally stated, the overall effect of the three additions of dilution water was to reduce total phosphorus, total nitrogen, and chlorophyll a levels and to increase water clarity (as measured by Secchi disc) in the lake. Improvement in Parker Horn itself was more marked than in other locations as replacement with dilution water is greater in Parker Horn. However, the effects of dilution extend much further than Parker Horn. Significant improvements in water quality were observed well into the lower lake and lower Pelican Horn, into the main lake, and even into Lewis Horn.

Nutrient Changes During 1977

Changes that occur due to the 1977 dilution program are related to the differing nutrient characteristics of upper Crab Creek and the Columbia River. Total phosphorus concentrations, as observed over the 1977 sampling program for each of these sources, are displayed in Table 2. Similar drops in nitrogen concentrations were observed.

Table 2. Comparison of Selected Water Quality Parameters[a]

Parameter	Goal	Parker Horn (Station 7)		Lower lake (Station 9)	
		1969	1977	1969	1977
Total phosphorus (μg/l)	50	135	78	135	91
Chlorophyll a (μg/l)	20	73	29	44	24
Transparency (Secchi disc, ft)	4.0	2.0	3.9	3.3	6.2

[a]Average values for stations indicated.

Chlorophyll Changes During 1977

Chlorophyll concentrations responded to dilutions more dramatically than the nutrients. Comparisons of stations in Parker Horn illustrate changes observed; by mid August, two months after dilution water had ceased, regrowth had occurred and nuisance conditions were prevalent.

Phytoplankton were identified and counted. Shifts in major population groups occurred throughout the period. From March through May diatoms were generally dominant coupled with a fair representation of greens; by June blue-greens had achieved dominance; and by August, when the nuisance chlorophyll concentrations had developed, the blue-greens peaked with 98 percent of the count observed on August 10. This large, blue-green algal biomass which existed at the beginning of the third and last dilution period was dominated by the genus *Aphanizomenon*. The decrease in chlorophyll following dilution was paralleled by a decrease in blue-green algae. The rapid decrease in blue-greens was accompanied by an increase in clean-water associated diatoms and green algae.

Transparency Changes during 1977

Secchi disc readings for Moses Lake in the Parker Horn-lower lake area clearly varied in response to changing water mixtures during and following the dilution experiments. Figure 2 compares 1969-1970 Secchi disc values with those observed during 1977 for middle Parker Horn. The data comparisons also reveal a more turbid condition existed in 1969 than in 1977. Major improvements in

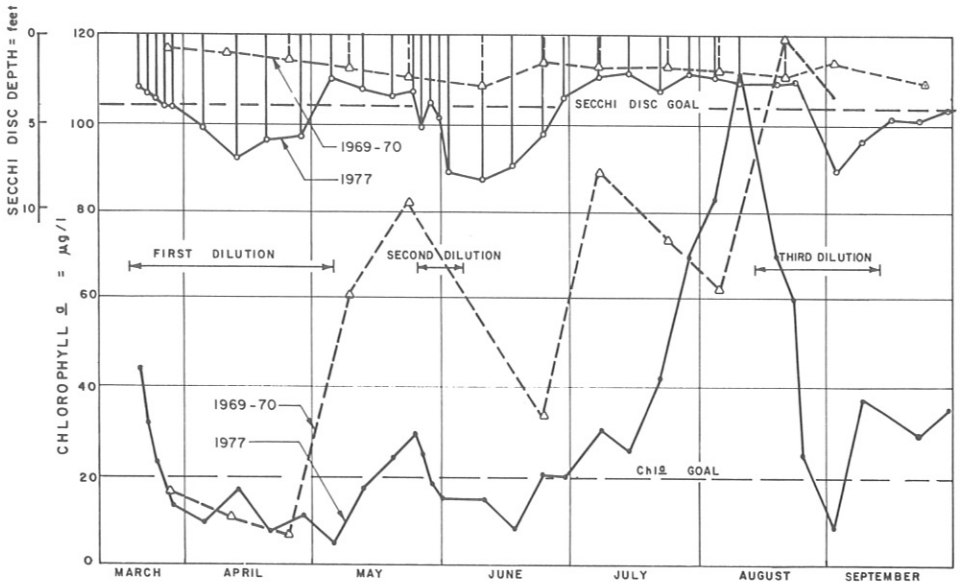


Figure 2. Middle Parker Horn Transparency and Chlorophyll a Changes during 1977

Secchi disc readings were observed with widespread achievement of the 4.0-foot transparency goal, often to the point that readings were double those in the baseline years (1969-1970). Explanations of transparency responses can be linked with chlorophyll and algal concentration measurements.

SUBSEQUENT DILUTION PROGRAMS

Release of dilution water into Parker Horn from the East Low Canal via Rocky Coulee Wasteway and Crab Creek has continued to occur over the past six years. Total amounts of water during spring and summer exceeded 100 million cubic meters (81,000 acre-feet) except during 1980-81, after the Mount St. Helen's ashfall, when total inputs were 34 and 69 million cubic meters, respectively. Approximately four inches (10 cm) of ash fell on the Moses Lake area and transport of that material into Crab Creek by wind and erosion was extensive. Dilution water inputs ranged from 117 to 258 million cubic meters during the other four years. However, during no year did a consistent release occur through the end of August. Average dilution water input rates ranged from 350 to 700 cfs (10 to 20 cubic meters per second). The pumping plant on the shore of Parker Horn transferred water from Parker Horn to Pelican Horn from April through July of 1982 and from April to early July in 1983. Undiluted water was pumped during August and September of both years. The discharge rate was constant at about 50 cfs.

Dilution affects progress as inflow water moves throughout the lake. Lake water is first displaced from Parker Horn, followed by displacement from the Rocky Ford Arm and the Lower Lake almost simultaneously. Once dilution water input ceases, undiluted high nutrient inflow water rapidly replaces diluted lake water. The shorter the period of dilution input, the faster high nutrient water returns. Increased algal biomass rapidly follows the return of high-nutrient water.

Water Quality Improvement

Although the pattern of dilution water input has been inconsistent over the past six years, the levels to which average algal biomass has been reduced and transparency increased (compared to predilution years) have remained rather similar. An exception was the considerably lower transparency and biomass during the ashfall of 1980. Otherwise, chlorophyll *a* has averaged 60 percent lower and Secchi transparency was nearly doubled over the six-year period of dilution, compared to predilution years of 1969 and 1970.

In spite of the impressive improvements in quality, intense algal blooms still occur during August and September with maximum chlorophyll *a* in excess of 60 ug/l and Secchi transparency less than one meter. These blooms occur following cessation of dilution input in July.

Nitrogen as the Controlling Nutrient

Nitrogen was limiting prior to the Mount St. Helen's ashfall. Phosphorus apparently became limiting during 1980 and 1981 following the ashfall. In 1980, the ratio of nitrate:soluble phosphate increased in Parker Horn and the lower lake, but the Total N:Total P ratio did not change. Chlorophyll *a* remained low, but unrelated to nitrate inflow during 1980 and 1981. However, the lake apparently returned to nitrogen limitation in 1982. The cause for this switch to phosphorus limitation is not well understood. The phosphate sorptive capacity of the ash deposit in the Creek may have resulted in a redistribution of phosphorus between soluble and particulate fractions. The lake is gradually returning to nitrogen limitation as indicated by the decreasing trend in average nitrate:soluble phosphate ratios in Parker Horn and the Lower Lake.

Although the nitrogen-fixer *Aphanizomenon* is the principal bloom former in Moses Lake, its growth rate when dependent on N-fixation is probably insufficient to permit utilization of the surplus soluble reactive phosphate. When growth rates are compared to the average water exchange rate in Parker Horn during summer, it is reasonable to assume that biomass increase of *Aphanizomenon* is most dependent on nitrate from the inflow. Increased detention time in the Lower Lake may result in greater contribution of N-fixation to algal biomass, but dilution there was still sufficient to reduce algal biomass.

Dilution of Pelican Horn

The input of diluted water from Parker Horn to Pelican Horn during July 1982 resulted in a marked reduction in algal biomass. Similar observations were made in 1983; however, data evaluations for 1983 are incomplete.

DILUTION WATER release point in Pelican Horn

Transparency in upper and middle Pelican Horn remained about the same as that during 1969-70 in spite of the markedly decreased biomass. The source of the turbidity was apparently non-algal.

Reduction of algal biomass, permanently in upper Pelican Horn and temporarily in middle Pelican Horn, was apparently due to the washout of algal cells in excess of their growth. Although there was less biomass following pumping of Parker Horn water to Pelican Horn, the benefits in improved water clarity were not realized. The persistent non-algal turbidity is probably due to the shallowness of this water body coupled with strong winds from the south and a larger abundance of carp. For that reason, it is not expected that transparency will markedly improve when sewage effluent is diverted. However, the severe nitrogen deficiency of algal cells should be lessened, since less phosphorus will be available. Thus pumping to Pelican Horn should have a greater negative effect on algal biomass.

FUTURE DILUTION WATER REQUIREMENTS

Optimum dilution water releases for Moses Lake should be at a moderate input rate from May through August. Water added too early (February-March) would be largely replaced by high-nutrient Crab Creek water by June when algal blooms begin. Replacement of diluted, low-nutrient lake water with high-nutrient Crab Creek water is also a problem if diluted water is stopped in June or early July. Unfortunately, the lack of irrigation demands and storage space in the downstream impoundment has made the supply of dilution water undependable during late summer. As a result, nuisance level blue-green blooms are still commonplace in August and September. Nevertheless, experience of the past six years indicates that around 100 million cubic meters (81,000 acre-feet) of release water during May through August should control chlorophyll _a_ to about 20 ug/l or less. Preferably this release should be continuous at a rate of 350 cfs (10 cubic meters per second) although the rate is less critical than the total volume.

The normal release pattern in which most of the water is added during April and May has resulted in Secchi disc transparencies of 4 meters which may be too great. Rooted vegetation, principally _Potamoqeton crispus_, has become abundant in upper Parker Horn in recent years, no doubt as a result of the greatly increased clarity. Adding the dilution water at a lower, but constant rate throughout the spring and summer should help control the spread of rooted plants. Transparencies in excess of 1.5 meters (5 feet) should be prevented if possible in order to discourage rooted aquatic plants.