POLLUTION CONTROL COMMISSION

STATE OF WASHINGTON

AN INVESTIGATION OF POLLUTION

In the

GREEN -- DUWAMISH RIVER

TECHNICAL BULLETIN NO. 20

SUMMER, 1955

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IN THE

GREEN-DUWAMISH RIVER

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REPORT SUMMARY

A survey of the Green-Duwamish River was conducted by the Pollution Control Commission during the summer of 1955 for the purpose of evaluating the river waters in regards to bacteriological contamination, dissolved oxygen conditions, and the effect of industrial wastes containing toxic compounds. Present and potential water uses were analyzed as to possible future flow deficits.

The results of the survey are summarized below:

1. The area under survey covered that portion of the Green-Duwamish River from immediately above Auburn down to and including the tidal estuary. Thirteen regular sampling stations were established, and the period of field sampling extended from June 23, 1955 to December 8, 1955.

2. Diversified use is made of Green River waters. The City of Tacoma diverts 100 second feet for domestic purposes and has on file an application for an additional 100 second feet. Seventeen second feet is presently being diverted for irrigation, and the ultimate demand is estimated at 113 c.f.s. Present industrial uses are small, but the trends indicate a much greater utilization in the future. In addition to direct water diversions, the Green River supports a very important commercial and sports fishery, evaluated at well over $1,000,000 annually.

3. Major sources of domestic sewage discharged to the Green-Duwamish River are: the effluents from sewage treatment plants located at Kent, Auburn and Seattle (Oregon St. plant); raw sewage from Seattle's numerous outfalls and overflow structures; and treated and untreated sewage from several industries located near the river.

4. There are ten sources of organic industrial wastes and thirteen sources of toxic industrial wastes discharging wastes to the river.

5. Water quality objectives pertaining to the Green-Duwamish River are as follows:

   A. Bacteriological - In waters to be used for sport fishing and boating, commercial fishing, log rafting and sorting, the most probable number of coliform bacteria should average less than 1000 per 100 milliliters in a representative number of samples.

   B. Dissolved Oxygen - To provide a satisfactory environment for fish and other aquatic life, the minimum dissolved oxygen concentration shall be 5 ppm.

   C. Concentration of toxic compounds - Standards established for those toxic compounds presently discharging to the Green River are: Cyanides - 0.5 ppm; chromates - 10.0 ppm; caustic - of such concentration that the pH of the receiving water is not raised over 9.0.

6. Bacteriological studies indicated the following:

A. Above Auburn the river was bacteriologically satisfactory since the average MPNs for the two control stations were 296 and 517. Immediately below Auburn, the average MPN value rose to 5,774, almost six times the recommended standard. Conditions were progressively worse downstream until at Station 12, the Spokane St. bridge, the average MPN was 36,321.

B. Studies made at the Kent, Auburn and Seattle-Oregon St. sewage treatment plants indicated that all three were unsatisfactory from the standpoint of adequate disinfection of the effluent.

C. Composite sampling surveys were made on the five Seattle sewers discharging on the west bank of the Duwamish and showed a total population equivalent of 13,080.

D. Ten industries with a combined total of 1935 employees discharge raw sewage directly to the river.

7. Results of dissolved oxygen samples taken throughout the summer at the 13 regular sampling stations indicated satisfactory conditions during the 1955 low flow period. However, the drop in oxygen concentration in the estuary during the low flow months of August and September indicated that, during extreme low flow years, concentrations in the estuary could become critical.

8. Studies conducted at industries having an organic waste indicated a total of 810 lbs of BOD (biochemical oxygen demand) per day discharging to the river, which equals a population equivalent of 4,850.

9. Studies made at the three sewage treatment plants to determine efficiencies in reduction of BOD and suspended solids showed that the Auburn and Oregon St. plants were not discharging satisfactory effluents. The survey at the Kent plant however, showed excellent BOD and solids reduction.

10. Industrial wastes containing toxic materials were, in general, adequately treated or diluted before discharge to the river. However, concentrations of toxic wastes have been high enough at times to be lethal to fish and aquatic life. Such highly toxic discharges have been due to poor management practices which allow accidental or careless spills and dumps.

11. When constructed, the Eagle Gorge Dam is supposed to provide adequate summertime flows for fish propagation and pollution abatement. However, an analysis of present and future uses of Green River waters indicates a potential flow deficit in the lower river during dry years, if the present plan of release of stored waters is used.

INTRODUCTION - PURPOSE AND SCOPE OF THE SURVEY

The effects of domestic sewage, industrial wastes, temperatures and minimum flows on the Green-Duwamish River have been of prime concern to fisheries management, pollution authorities and health agencies for many years. Since the Green River is extremely important as a salmon and steelhead producer, the Department of Fisheries and the Department of Game are vitally interested in the promotion and continuance of successful spawning runs. The Department of Health is concerned about the bacteriological quality of the water to be utilized for domestic supplies, irrigation and other uses. Prevention and correction of pollution problems, in order that the water quality of the Green River is satisfactory for the above water uses, is the responsibility of the Pollution Control Commission.

Many surveys of various types have been made on the river in past years, but since the factors governing the quality of the water have changed and are changing so rapidly, the need was apparent for an up-to-date survey to correctly determine and evaluate the present conditions of water quality. The problems of an adequate quantity of water to meet the expanding needs of domestic water supplies, irrigation, industrial users and fisheries was also investigated and evaluated.

The survey was conducted during the summer and fall months of 1955 by the survey staff of the Pollution Control Commission with the following objectives under consideration:

1. To determine the degree of sewage contamination in the Green River resulting from discharge of raw and treated sewage.

2. To determine dissolved oxygen conditions in the river and to establish responsibilities for any oxygen deficits which may exist.

3. To determine the degree of any toxic condition which may exist in the river as a result of discharge of industrial waste or wastes.

4. To evaluate present and future uses of Green River waters in order to recommend safe minimum flows necessary to sustain fish life and to afford adequate dilution of treated domestic and industrial wastes.

The area under survey covered that portion of the Green River from just above Auburn down to and including the tidal estuary.

DESCRIPTION OF THE SURVEY AREA

Originating in the Cascade Range at an elevation of about 5000 feet, the Green River flows north and west about 60 miles to the junction with the Black River. Below the junction it is known as the Duwamish River and flows north 12 miles and enters Elliott Bay at Seattle. In its upper reaches, the river is swift and turbulent as it flows through terrain characterized by sharply incised valleys and high ridges. As it emerges from the hills and onto the flood plain just above Auburn, the velocity decreases and the Green River becomes relatively placid as it flows through the fertile Auburn and Kent valleys.

Originally, the Duwamish River drained an area of some 1600 square miles which included the White River drainage basin. In 1906, an extreme flood diverted the White into the Stuck River and thence to the Puyallup, thereby reducing the drainage area by 870 square miles. The diversion was made permanent by the construction of a concrete diversion dam. Upon completion of the Government Locks at Ballard in 1916, the level of Lake Washington was lowered and the Black River no longer formed its outlet. This action reduced the size of the drainage area still more, and at the present time, the Green-Duwamish River drains a basin of 470 square miles.

The lower Duwamish flows through a heavily industrialized section of Seattle and enters Elliott Bay via the West Waterway. During high water, the East Waterway carries part of the discharge. Approximately five miles of the lower Duwamish have been improved for navigational purposes.

WATER USES

Water Supplies

The City of Tacoma derives its principal source of domestic water supply from Green River headwaters. Approximately 230 square miles of drainage area above the point of diversion serve as the watershed, with the city having discretionary powers without ownership, over this area. The headworks and intake structure are located three miles upstream from Palmer, and Tacoma presently has an existing water right for 100 second feet. The pipeline from the intake structure to Tacoma proper has a capacity of 80 second feet; consequently, that is the amount presently being diverted for the city's water uses.

An application for an additional 100 second feet has been filed by Tacoma to meet their expanding water needs. Anticipated diversions such as these call for careful water management to provide for adequate flows to satisfy water needs for all interests, especially fisheries.

Irrigation

At the present time, 41 water users take a total of 17 second feet from the Green River for irrigation purposes. The Department of Agriculture estimates an addtional 96 second feet will ultimately be needed for irrigable land in proximity to the river.

Fisheries

The Green River and its principal tributaries are extremely important to the fisheries economy of Puget Sound and the State as a whole. Both the commercial and sports fishery depend on rivers such as the Green-Duwamish to maintain adequate populations of salmon, and the Green is especially significant in the production of chinook, silver and chum salmon, and steelhead. Since the diversion of the White River in 1906, the pink salmon have declined in numbers until they are now considered negligible insofar as their commercial significance is concerned.

In general, the salmon spawning grounds lie in the main river between Auburn and Newaukum Creek and in three of the tributary streams; namely, Soos Creek, Burns Creek and Newaukum Creek. Natural spawning is augmented by the large State hatchery maintained on Soos Creek for the artificial propagation of silver and chinook salmon. The magnitude of the hatchery operation can be seen from the following egg-take statistics:

Year	Egg-Take Chinooks	Egg-Take Silvers
1952	7,628,430	5,176,125
1953	10,769,350	4,462,588

Of the total number of adult spawners, an estimated 16% of chinooks and 33% of silvers return to Soos Creek. The rest of the runs spawn in the main river and, to a lesser degree, in other tributaries.

Commercial Fisheries: It is difficult to accurately evaluate the annual commercial value of salmon produced by the Green-Duwamish River because the catch is distributed over such a wide area in Puget Sound and coastal waters. However, by tagging experiments, fish escapement counts, observation studies, etc., a reasonably valid value can be estimated. The State Fisheries Department made such an evaluation study in 1946 and set the annual value of the Green River salmon at $431,000. This figure was based on 1946 prices, and would be considerably higher based on present day market values.

Sport Fisheries: A large salmon sports fishery exists in Elliott Bay, almost all of which is attributed to salmon originating in the Green River. It is difficult to evaluate a sports fishery on a monetary basis; various agencies use various methods. The State Department of Fisheries places an annual value of $394,000 on the Elliott Bay sports fishery, on the basis of $1.00 per pound of fish caught. This value has proved quite valid when all the costs are computed, including boat and motor rentals, bait and gear costs, transportation, etc.

Steelhead fishing in the State of Washington has accelerated tremendously in recent years. In 1941, according to State Department of Game statistics, a total of 7,840 fishermen caught 1,729 steelhead. In the 1954-55 season, 11,101 steelhead were caught in 62,166 man days of fishing. $6.00 per man day of fishing is accepted as an average expenditure, so the State Game Department places a value of $372,996 on the steelhead fishery for the 1954-55 season.

From the above evaluations, it appears that the Green River fishery is worth well over $1,000,000 annually. The continuance of such a profitable fishery depends to a large extent on the maintenance of satisfactory chemical and physical conditions in the waters of the Green River.

SOURCES OF DOMESTIC SEWAGE

Although the Green River is not used to any appreciable extent for swimming and bathing purposes, the extensive sport fishery on the upper river, and log-rafting and boating on the lower river necessitate good bacteriological water quality. Treatment of domestic sewage with adequate disinfection of the effluent is necessary not only to maintain satisfactory bacteriological quality but also to reduce the oxygen demand of sewage wastes. The dissolved oxygen concentrations in the lower Duwamish are down to the minimum deemed advisable for satisfactory aquatic life conditions, especially during summertime low flow conditions. The minimum oxygen conditions prevail in the lower end of the Duwamish and are largely due to the discharge of raw sewage from Seattle's numerous sewer outfalls and to discharge of industrial waste waters.

Sewage Treatment Plants

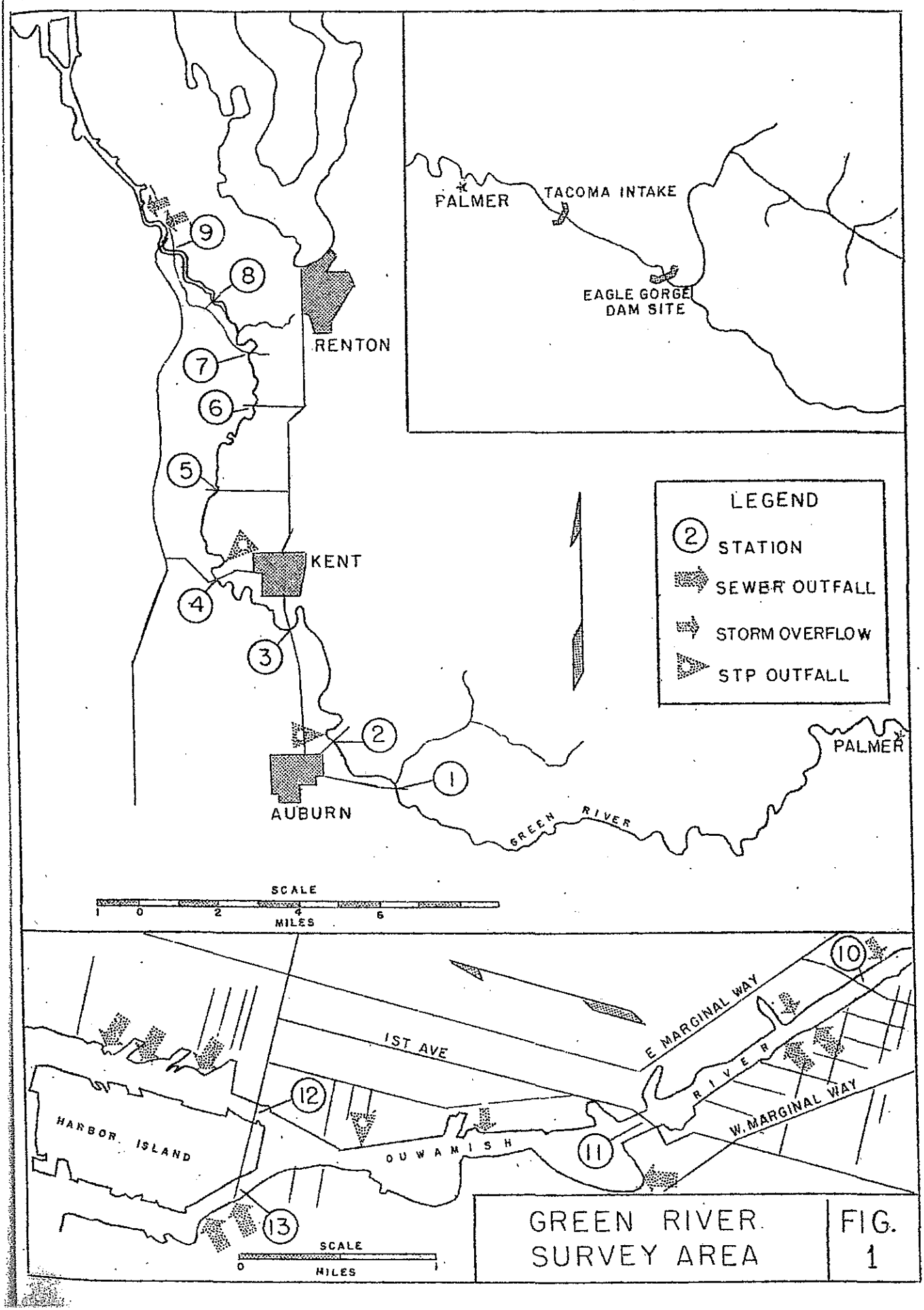
Auburn - - - Population 7,250. Originally sewage from the City of Auburn was treated by a septic tank plus chlorination of the effluent. The inadequacy of the treatment facilities was partially overcome by the additional construction of a headworks, clarifier, contact chamber and sludge digester.

Kent - - - Population 3,675. Until early in 1955, the City of Kent discharged its combined sewage directly to the Green River via an obsolete, ineffective, septic tank. Upon completion of the new sewage treatment plant, all sewage, both industrial and domestic, now receives intermediate treatment before discharge to the river. This new plant is especially beneficial to the river because of the reduction in the heavy organic load formerly contributed by the numerous food processing plants located in Kent.

Seattle: (Oregon Street) - - - The City of Seattle maintains a primary sewage treatment plant at the foot of West Oregon Street on the east bank of the Duwamish. This plant, constructed in 1938, treats sewage from South Lake Washington and part of the Duwamish Valley. Planned originally for a contributing population of 32,000 the plant is now operating in excess of its designed loading.

Seattle Sewer Outfalls

From the Highway 99 Bridge north to the river mouth, the Duwamish receives the discharge from numerous sewer outfalls and overflow structures from the Seattle sewer system. An estimated population of 95,000 is presently served by sewers discharging to the Duwamish; the estimated future population for the same area is 192,000. The locations of the 8 sewers and 4 overflows are shown in Figure 1. Seattle sewers have been designed largely to carry both storm water and sanitary sewage, a factor which now complicates the sewage treatment problem.



GREEN RIVER SURVEY AREA

FIG. 1

SOURCES OF INDUSTRIAL WASTES

Numerous industries, located from above Auburn down to the river mouth, discharge their wastes directly to the Green-Duwamish River. Many more within the corporate limits of the City of Seattle are served by the municipal sewer system, which in many instances discharges to the Duwamish without treatment. Following is a list of the principal industries which discharge directly to the river. Most of these industries have initiated recovery or treatment projects as will be discussed in detail later in the report.

TABLE 1

Industry	Location	Type of Waste and Specific Items in Effluent
Auburn Packing Co.	Auburn	Organic - wash water, etc.
Miller Packing Co.	Renton	Organic - wash water, etc.
Seattle Rendering Co.	Renton	Organic - wash water, etc.
Green River Cheese Co.	Tukwila	Organic - wash water, etc.
Boeing Airplane Co.	East Side River	Toxic - cyanides, chromates
Nat'l Fruit Canning Co.	"	Organic - wash water, etc.
Pankratz Lumber Co.	"	Organic - wood wastes
Bethlehem Steel Corp.	"	Toxic - caustic wash water
Nat'l Steel Const. Co.	"	Toxic - acid wash water
Kenworth Motor Truck Corp.	"	Toxic - diluted caustic wash
Rheem Mfg. Co.	"	Toxic - neutralized pickling liquor
American Wine Growers	"	Organic - wash water
Pacific Rendering Co.	"	Organic - wash water, etc.
Northwest Cooperage Co.	West Side River	Toxic - caustic wash & rinse
A & B Barrel Co.	"	Toxic - caustic wash & rinse
City Packing Co.	"	Organic - wash water, etc.
Reichhold Chemical Co.	"	Toxic - phenol, pentachloro-phenol
Western Oxygen, Inc.	Harbor Island	Toxic - lime, some acetylene
Todd Shipyards Corp.	"	Toxic - accidental oil spills
Puget Sound Bridge and Dredging Co.	"	Toxic - accidental oil spills
American-Marietta Co.	"	Toxic - phenols, formaldehyde, etc.
Fisher Flouring Mills Co.	"	Organic - wash water
West Coast Wood Preserving Company	West Waterway	Toxic - sodium arsenate

STANDARDS OF WATER QUALITY

Wastes discharged to the Green-Duwamish affect the river in essentially three ways: 1. Bacteriological contamination. 2. Reduction in dissolved oxygen concentrations. 3. Introduction of toxicants. Following is a brief discussion of these three factors as they affect water quality.

Bacteriological Contamination

To determine the bacteriological quality of the Green River, two steps were necessary; first, a sanitary survey to determine the sources of sewage discharge and, second, a bacteriological survey to determine the degree of contamination.

Bacteriological surveys involve the detection and determination of the number of organisms of the coliform commonly known as B. coli or colon bacillus. These coliform organisms are normal inhabitants of the intestinal tract of man and are excreted in large numbers. They are not, in themselves, disease producing. Their presence in water known to be polluted by human sewage is indicative of the possible presence of the less detected disease organisms, such as those that cause typhoid fever, amoebic dysentery and bacillary dysentery.

The bacteriological test for coliform organisms involves not only the detection of the organism in a sample of the water, but the number of organisms present. Results of such tests are reported as the most probable number of coliform organisms per 100 milliliters of the water tested (abbreviated as MPN). 100 milliliters of water is approximately $3\frac{1}{2}$ fluid ounces, or about half a cup. Thus, when the MPN of a sample of water is given as 240, it would mean that 100 ml. or one half cup of that water sample would contain 240 coliform organisms.

In establishing a standard or objective of bacteriological water quality, the use or uses to which the waterway in question will be put serves as the criteria. In the case of the Green-Duwamish River, sport fishing, log-rafting and boating are the principal means by which bodily contact can be made with the waters of the river.

The objective generally accepted by the States of the Pacific Northwest is as follows:

> Sport fishing and boating, commercial fishing, log rafting and sorting -- the most probable number of coliform bacteria, when associated by means of a sanitary survey with domestic sewage "should average less than 1000 per 100 ml. in a representative number of samples, and should not exceed this number in more than 20 percent of the samples examined".

Dissolved Oxygen

One of the most important characteristics of a body of water is its dissolved oxygen concentrations (D.O.), which is usually expressed in terms of parts per million (ppm). In other words, if a D.O. concentration is given as 7 ppm, it means that of a million parts of water, 7 parts are made up of oxygen. Water does not readily absorb oxygen, consequently concentrations in excess of 10 to 11 ppm are seldom found even in clear, cold, unpolluted water.

According to standards in general acceptance by fisheries interests and pollution control authorities, a minimum of 5 ppm D.O. is essential to maintain fish and other aquatic life. It's true that fish can survive in water containing as little as 2 ppm, but fish, especially salmon, cannot thrive and maintain proper growth rates, immunity to disease, etc., at those concentrations. Therefore, when D.O. values for a body of water descend to

5 ppm or lower, conditions are considered to be reaching the critical stage.

Biochemical Oxygen Demand

One of the common tests used in making pollution surveys is biochemical oxygen demand (B.O.D.). All organic wastes and many chemical wastes exert a demand for oxygen when they are discharged to a waterway. Bacteria and other small organisms use organic matter in wastes for food and in their life processes combine this material with the oxygen in the water. In the case of chemical wastes there may be a direct chemical affinity of the waste for oxygen. However, the end result is the same -- available oxygen is removed from the water. It follows, then, that if a waste or wastes have a sufficient demand for oxygen (B.O.D.), the D.O. concentrations could be lowered to the point where critical conditions for fish and aquatic life could exist.

BOD is expressed in terms of parts per million. That is, if BOD of a waste is 100 ppm, it means that one million parts of that waste would require 100 parts of oxygen to satisfy its oxygen demand. The BOD of any waste can be determined by laboratory procedure.

If the quantity of waste from an industry or municipality is known, the BOD can then be expressed as pounds per day, since 1 ppm is equal to 8.34 pounds per million gallons. In evaluating the waste from any industry, the volume is especially important, in that a weak waste with a large volume may be as detrimental as a strong waste with less volume.

Toxicants

Several industries located on the lower Duwamish discharge wastes with toxic properties. (See Table 1). In general, the concentration of the toxic element in the waste is the important factor, in determining how critical that waste will be when it is introduced into a waterway. Fish and other aquatic organisms have a tolerance level for essentially all known toxic elements. If the concentration of the toxicant is below that tolerance limit, fish can survive without appreciable mortalities. In the case of the Duwamish industries, essentially all of them discharge wastes with concentrations of toxicants below these limits. The exception occurs when there are accidental or careless spills and dumps within the industry. When such a "slug" reaches the waterway, an area of high toxicity may result until adequate dilution takes place. Standards for concentration of toxicants are established well below the toxicity threshold to provide a safety factor and to avoid effects which may weaken the fish.

RESULTS OF BACTERIOLOGICAL STUDIES

Thirteen regular sampling stations were established, covering the river from above Auburn down to the East and West Waterways. (See Figure 1). A total of 14 samples were collected at each station, covering a period of time from June 23 to October 11, 1955.

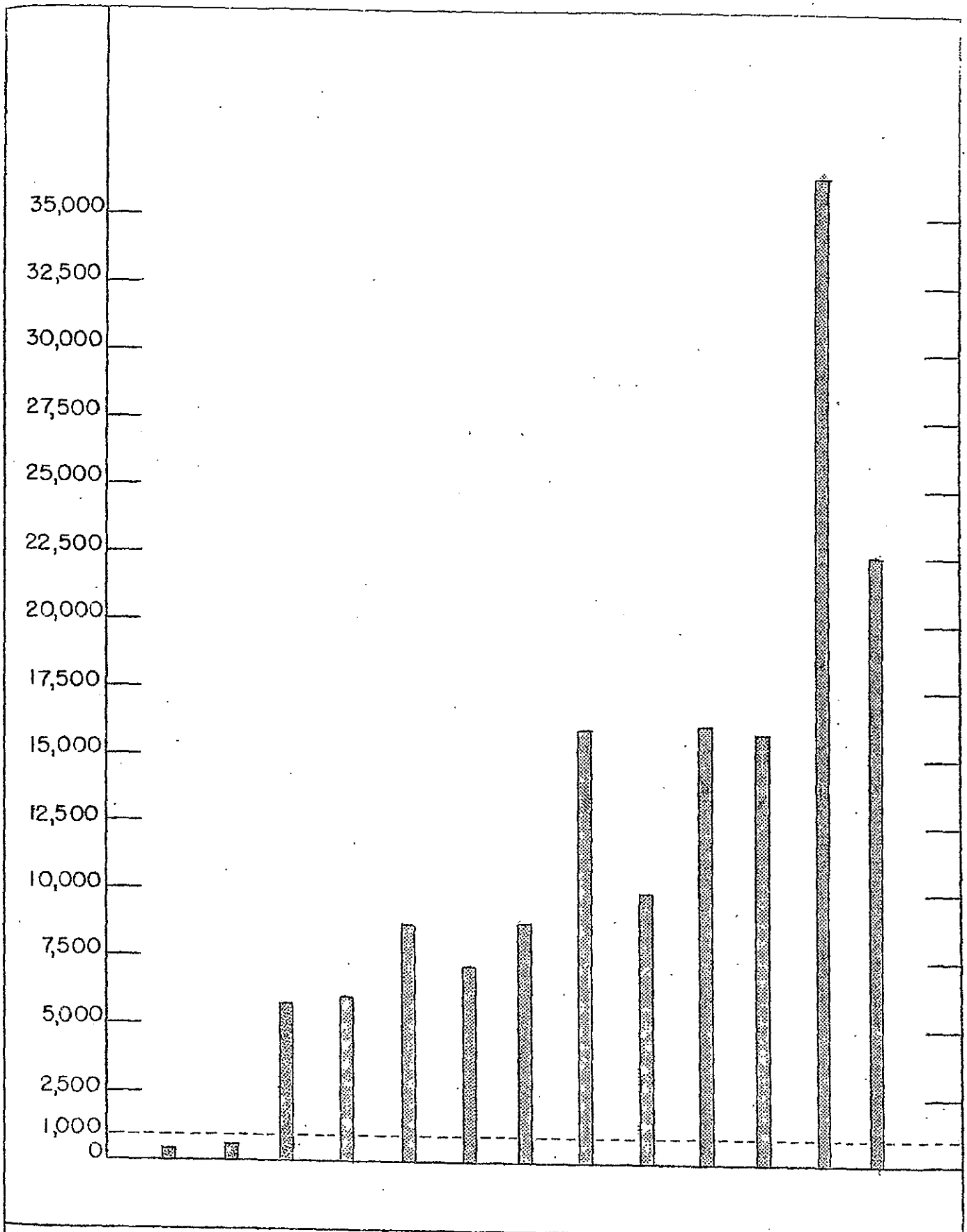
The following table shows maximum, minimum and average MPNs for the thirteen stations. Figure 2 indicates the same data in a graphic form, comparing the average MPNs of the thirteen stations with the previously mentioned water quality objective of 1000 for purposes such as sport and commercial fishing, and log rafting and sorting.

TABLE 2
SUMMARY OF BACTERIOLOGICAL DATA

Station No.	Location	MPN		
		Max.	Min.	Ave.
1	Maple Valley Bridge - Auburn	2,100	23	296
2	Porter Bridge - Auburn	2,400	60	517
3	Bridge between Auburn & Kent	69,000	60	5,774
4	Bridge above Kent STP outfall	24,000	130	5,934
5	O'Brien Bridge	24,000	60	8,761
6	Orillia Bridge	24,000	60	7,174
7	Tukwila Bridge	24,000	230	8,894
8	Foster Bridge	69,000	230	16,962
9	Highway 5-M Bridge	24,000	230	10,010
10	16th Ave. Bridge - Seattle	69,000	620	15,281
11	W. Michigan St. Bridge - Seattle	69,000	230	14,874
12	Spokane St. - East Waterway	130,000	2,400	36,321
13	Spokane St. - West Waterway	130,000	2,400	22,443

Stations 1 and 2 served as control stations and results indicate that the bacteriological water quality is fairly good as the river emerges from the hills and onto the flood plain above Auburn. The influence of the effluent from the Auburn treatment plant can be seen in the results for Station 3. The average MPN here is almost six times the recommended objective for sport fishing.

Below Kent the average MPN rises again and remains fairly constant down to the Foster Bridge. Local contamination at this point from domestic sewage and packing plant wastes raises the average coliform count to almost 17,000. The drop in averages to 10,000 at the 5-M Bridge is followed by an increase to an ultimate value of over 36,000 as the Duwamish enters Elliott Bay in spite of the added dilution due to tidal action. In this area the influence of raw sewage from the numerous Seattle sewers is clearly seen.



AVERAGE COLIFORM COUNTS
REGULAR SAMPLING STATIONS

FIG. 2

Previous Surveys

To evaluate changes that may have occurred over a period of years, the 1955 data was compared with data collected at similar stations on previous surveys. In Table 3 are listed the 1955 averages, averages for 1949 survey conducted by the Pollution Control Commission, and averages for a survey conducted by the Seattle Engineering Department. (Samples averaged for each month from November 1948 to April 1950).

TABLE 3
COMPARISON OF BACTERIOLOGICAL DATA

Station	City of Seattle 1948-50	P. C. C. 1949	P. C. C. 1955
2		747	517
4		787	5,934
7		67,400	8,894
9	21,600		10,010
10	7,300	12,671	15,281
11	11,855		14,874
12	7,000		36,321
13	12,094	14,921	22,443

By comparison, it appears that bacteriological conditions are now worse below Auburn, considerably better below Kent to the Highway 99 Bridge, and appreciably worse in the lower Duwamish. The improvement below Kent can be attributed to the new Kent sewage treatment plant; the rise in MPNs in the lower Duwamish is presumably due to the increase in the amount of sewage discharged by Seattle sewers and to the increased amounts of domestic sewage from industries.

Sewage Treatment Plants

As a part of the regular program of operational checks on sewage treatment plants, efficiency studies are conducted to determine the efficiency of BOD and solids reduction, and reduction in the numbers of coliform organisms. Two such studies were made on the Auburn sewage treatment plant, one on December 28, 1954 and again on August 25, 1955. Results were as follows:

Date	S.T.P. Flow	% Reduction in Coliform organisms	Average MPN of Effluent
12-28-54	802,000	89.3	1,165,000
8-25-55	608,000	99.7	54,100

A similar study conducted at the Kent sewage treatment plant on August 18, 1955 indicated the following:

STP Flow Gals/Day	% Reduction in Coliform organisms	Average MPN of Effluent
2,300,000	98.7	334,600

On September 1, 1955 an efficiency study was made on the Oregon Street sewage treatment plant operated by the City of Seattle. Results were as follows:

STP Flow Gals/Day	% Reduction in Coliform organisms	Average MPN of Effluent
4,380,000	90.9	2,115,000

Judging from the percent reduction and the average MPN of the effluents it is apparent that all three of the plants are unsatisfactory from the standpoint of adequate chlorination (disinfection) of the effluent.

Domestic Sewage from Industries

In addition to industrial waste waters, many industries discharge domestic sewage directly to the waterway. In the case of the larger industries with a considerable number of employees, the domestic sewage discharge can be of appreciable volume and quite significant in evaluating the total waste load contributed to any waterway. Following is a list of industries that are located in proximity to the Green-Duwamish and discharge their domestic sewage directly to the river:

TABLE 4

Industry	Number of Employees	Location
Green River Cheese Co.	4	Tukwila
National Steel Construction Co.	200	East Side - Duwa
U. S. Plywood Lumber Div.	125	"
Superior Portland Cement	80	"
Pacific Rendering Co.	6	"
Northwest Cooperage	25	West Side - Duwa
City Packing Co.	45	"
Todd Shipyards	500 +	Harbor Island
Puget Sound Bridge & Dredging Co.	500 +	"
Fisher Flouring Mills	450	"
	1935	

Most of the industries listed above discharge to the Duwamish because municipal sewers have not been provided. However, treatment of domestic sewage by adequate septic tank facilities followed by chlorination would provide a satisfactory effluent until the city provides sewers and treatment.

RESULTS OF DISSOLVED OXYGEN STUDIES

Dissolved oxygen samples were collected at the same time and at the same stations as the bacteriological samples. Listed below in Table 5 are the dates and D.O. values for each of the 14 samples collected at the 13 stations. Station locations are listed in Table 2 and depicted in Figure 1.

TABLE 5
SUMMARY OF DISSOLVED OXYGEN DATA

	Stations												
Date	1	2	3	4	5	6	7	8	9	10	11	12	1
6-23	11.2	11.0	10.4	10.9	10.9	10.6	10.5	10.4	10.6	10.4	10.2	9.6	9.
6-29	11.2	11.0	10.8	10.6	10.4	10.4	10.3	10.3	10.2	10.1	9.9	9.3	9.
7-5	11.4	11.1	10.6	10.4	10.3	10.3	10.3	10.2	10.1	9.9	9.6	7.9	9.
7-13	10.3	9.8	9.6	9.5	8.9	9.2	9.1	8.9	8.9	9.1	8.8	8.2	8.
7-26	10.1	9.4	9.6	8.6	8.8	8.7	8.5	8.3	8.3	7.9	8.0	7.2	7.
8-9	9.9	9.6	9.6	9.1	8.6	8.6	8.3	8.1	8.1	7.5	7.4	6.7	6.
8-17	9.7	9.1	9.1	8.6	8.1	8.0	8.1	7.8	7.6	7.0	6.8	5.3	6.
8-24	9.9	9.1	9.4	8.6	8.3	8.2	8.2	8.3	7.4	7.5	7.5	7.1	6.
8-31	9.6	8.9	8.9	8.9	7.7	7.6	7.7	7.3	7.5	6.2	6.1	4.9	6.
9-7	9.3	8.6	8.3	7.6	7.6	7.7	7.6	6.8	6.5	6.7	6.6	5.9	6.
9-14	10.3	9.5	9.6	8.9	8.5	8.5	8.2	7.8	7.5	6.0	4.8	6.5	6.
9-28	10.3	9.6	9.4	9.0	9.0	8.7	8.9	8.5	8.0	6.2	6.2	6.5	5.
10-5	10.9	10.5	10.3	9.8	9.7	9.6	9.5	9.2	8.4	6.8	6.7	6.4	5.
10-11	11.4	11.2	11.1	10.9	10.8	10.7	10.6	10.4	10.4	9.9	9.8	9.2	9.

From the data presented in the above table, it is apparent that oxygen conditions were, in general, satisfactory during the low flow period in 1955. On only two occasions did the D.O. concentrations drop below 5 ppm (August 31 at station 12 and September 14 at station 11). However, 1955 was a year of lower water temperatures and higher minimum flows than normally can be expected. The graphical presentation of discharge of the Green River (Figure 3) indicates that for only a short time in September did the flow drop below 250 cfs. (Auburn Gaging Station).

In 1953, however, flows below 200 second feet existed for 24 consecutive days at Auburn and in 1952 for a period of 125 continuous days. During that low flow period in 1952, there was a 23-day period with flows below 100 second feet. In 1951, a similar condition existed with the flow below 200 second feet for a period of 71 consecutive days.

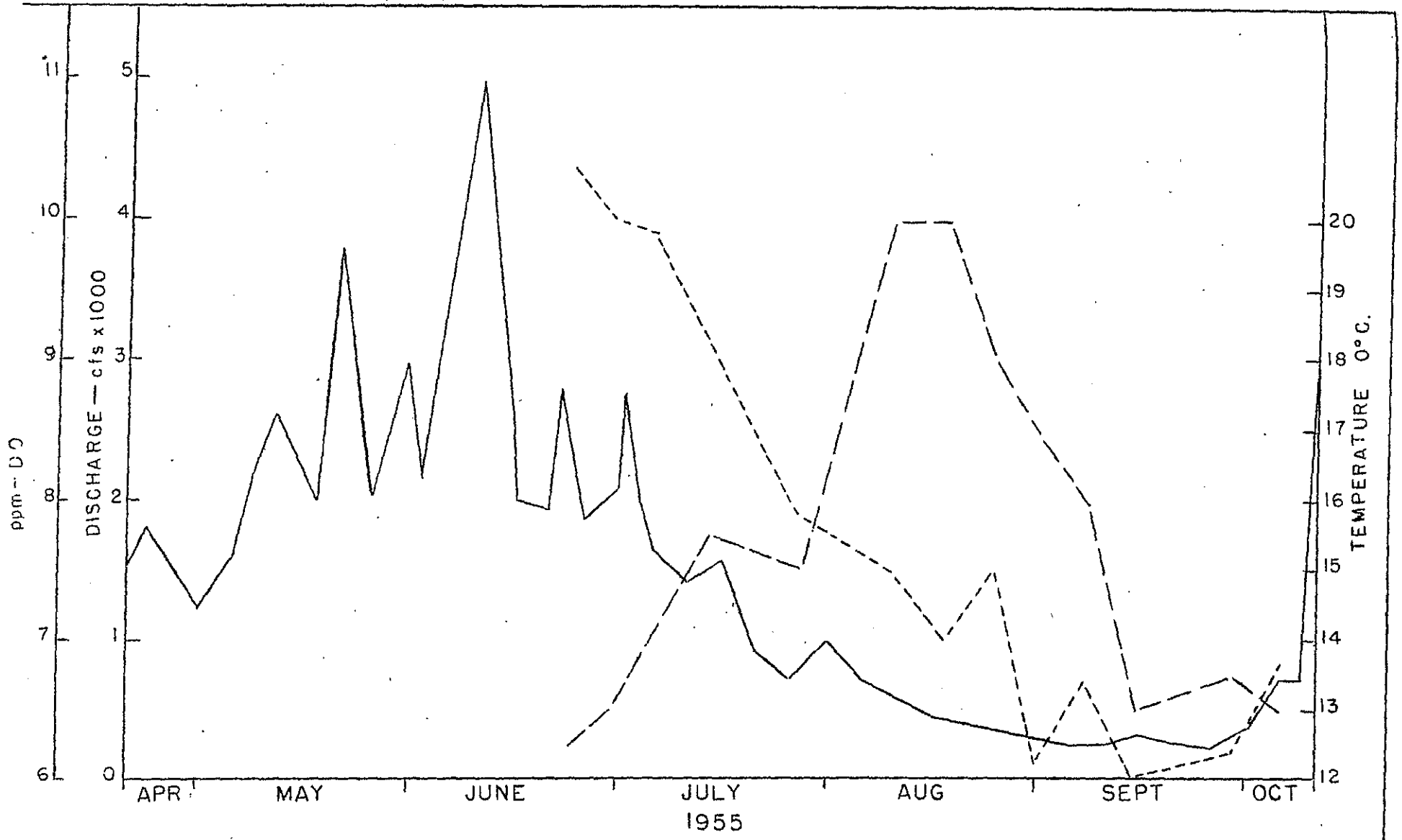


FIG. 3

DISSOLVED OXYGEN VS. FLOW AND TEMPERATURE
STATION 10

Consequently, although critical oxygen concentrations (below 5 ppm) did not prevail in the river in 1955, it appears certain that adverse conditions could exist during a low water year in the estuary portion of the Duwamish.

Figure 4 indicates the oxygen curve for the river on two different days of survey, August 31 and September 14. The influence of oxygen demanding wastes can be seen by comparing the oxygen saturation curve with the actual D.O. curve. The sag from Station 8 seaward is presumably due to the amount of organic waste discharged in the lower Duwamish. Data at Stations 12 and 13 indicates an upward swing in the curve which is due to the influence of sea water carried into the estuary by tidal action. Salinity tests made on samples taken during the survey indicate noticeable tidal effects as far upstream as the Black River junction near Tukwila.

RESULTS OF BOD STUDIES

It was determined that the oxygen demanding wastes discharged to the river were essentially organic in nature and came from three types of sources; industrial waste, effluents from sewage treatment plants and raw sewage. Composite samples were collected at various sources and the strength and amount of each waste were determined. Following are the results of the various studies, expressed in terms of biochemical oxygen demand (BOD), suspended solids (S.S.), and total solids (T.S.).

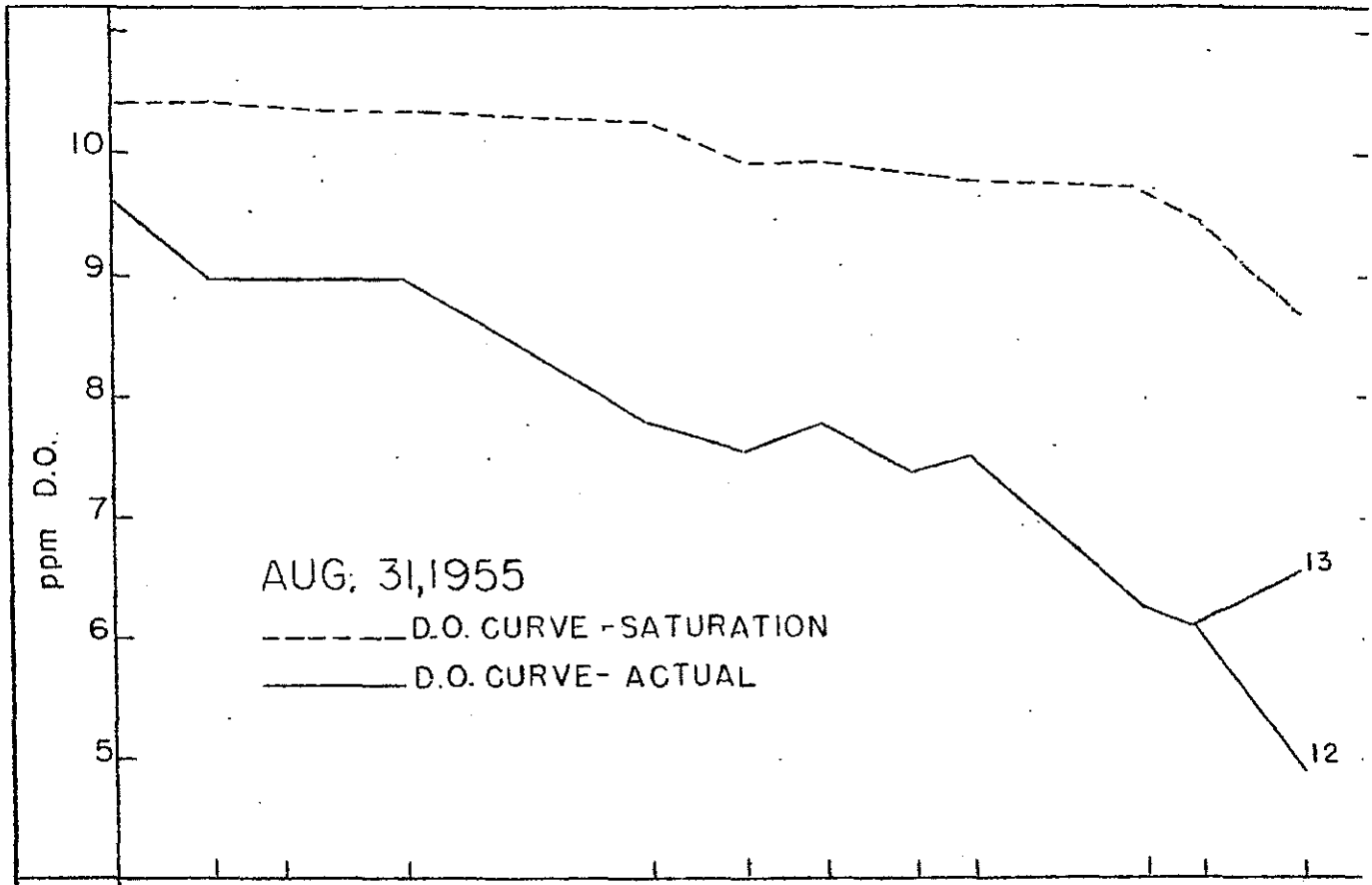
Industries

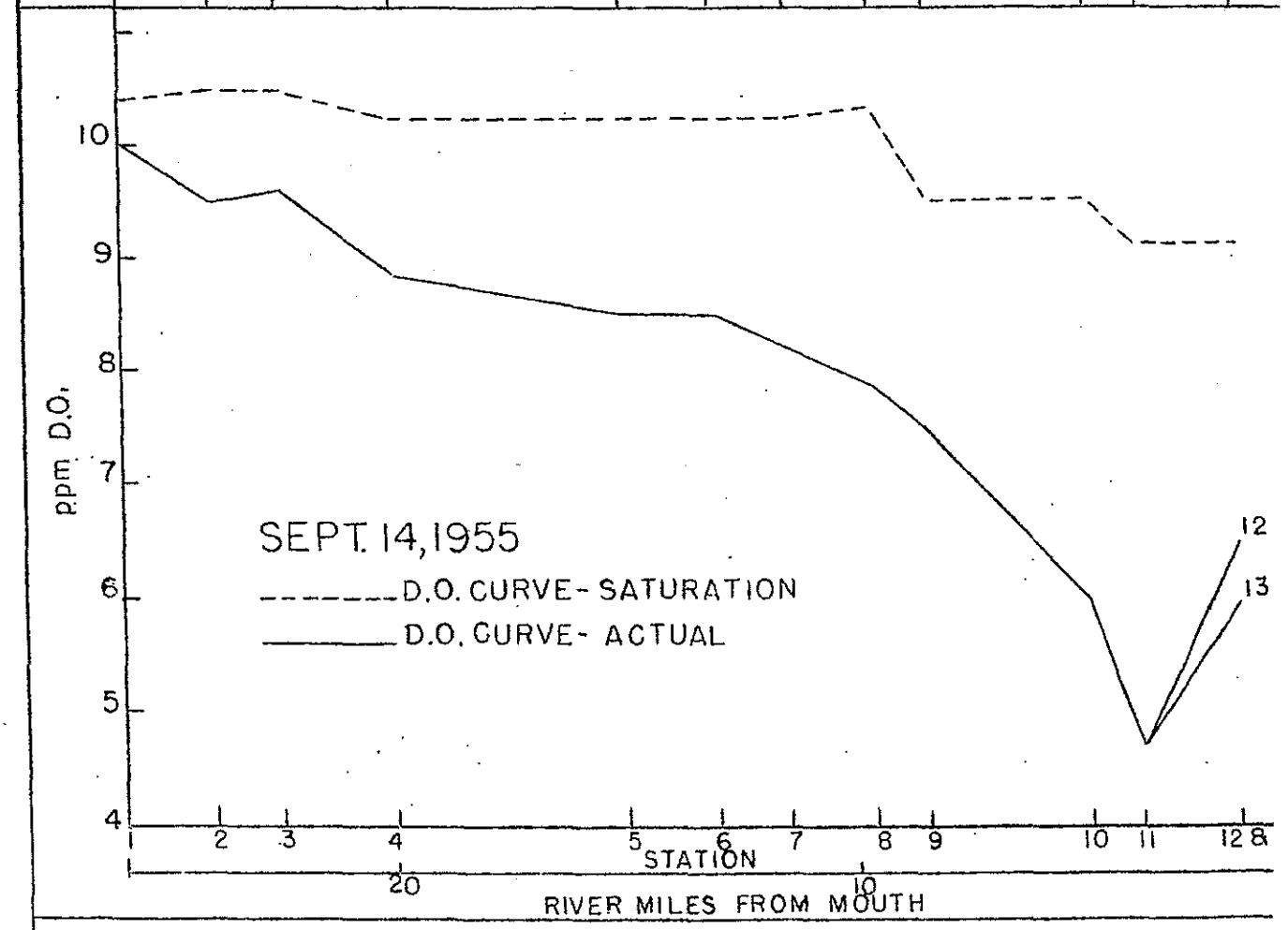
Auburn Packing Co., Auburn - - - Located upstream from Auburn on a small slough, the Auburn Packing Co. processes about 100 beef per day. Waste preventive methods consist of grease recovery, blood collection and drying, and collection of paunch manure. Sanitary sewage is treated by a septic tank and drainfield. On July 29, 1955, a survey and subsequent analysis of the plant waste revealed the following:

Water usage:	97,000 gals/day
B.O.D.:	638 ppm or 170 lbs/day
S. S.	281 ppm
T. S.	860 ppm

The plant effluent is discharged to a slough paralleling the Green River. During the low flow period, the slough does not discharge to the river; instead it performs somewhat the function of a lagoon. Discharge to the river proper occurs during higher flows and, hence, during less critical conditions.

Miller Packing Co., Renton - - - The Miller Packing Co., is located on the Green River near Tukwila and discharges waste directly to the river. Approximately 25 beef are killed at this plant per day with a minimum of waste prevention measures. Paunch manure is collected but there are no facilities for the collection of blood. Liquid wastes pass through an ineffective grease trap before release to the river. However, plans are being completed for better waste treatment facilities and present deficiencies will be corrected prior to the low flow stages of the river in 1956.





DISSOLVED OXYGEN VS. SATURATION FIG.

Water usage:	8,000 gals/day
B.O.D.:	6,380 ppm or 148 lbs/day
S. S.:	166 ppm
T. S:	5,558 ppm

Seattle Rendering Co., Renton - - - Located downstream from Tukwila, the Seattle Rendering Co., processes meat scraps, dead stock, slaughterhouse offal and fish into tallow and meal. The plant operates 24 hours per day and discharges waste waters to the Green River. Treatment consists of traps for grease recovery, and appear to be adequate if properly maintained. The principal source of waste comes from the gut washer which operates about two hours a day. An analysis of the waste was made on August 11 with the following results:

Water usage, main sewer:	141,000 gals/day
B.O.D.:	87 ppm or 102 lbs/day
S. S.:	19 ppm
Water usage, gut washer:	4,800 gals/day
B.O.D.:	3,492 ppm or 12 lbs/day
S. S.:	22,000 ppm

Green River Cheese Co., Tukwila - - - The Green River Cheese Co., is quite small in operation and makes a very minor contribution of waste to the Green River. A waste analysis made on August 3, 1955 indicated the following:

Water usage:	1,550 gals/day
B.O.D.:	628 ppm or 3 lbs/day
S. S.:	202 ppm
T. S.:	1,776 ppm

National Fruit Canning Co., 1720 W. Spokane St., Seattle - - - Products of this plant are canned apples, cherries, currants and strawberries. Waste preventive measures consist primarily of dry removal of solid wastes; all liquid waste being discharged to the Duwamish. On the day of survey, December 6, 1955, apples were being processed, and the waste analysis for that day's pack is as follows:

Water usage:	83,600 gals/day
B.O.D.:	816 ppm or 190 lbs/day
S. S.:	192 ppm

American Wine Growers, 9417 E. Marginal Way, Seattle - - - The American Wine Growers Co.. operates essentially as a distilling and bottling plant. Pomace and lees are hauled to the city dump. Liquid wastes are contributed principally by the cleaning of equipment and vat washing. Results of a survey made on December 8, 1955 indicated the following:

Water usage:	7,550 gals/day
B.O.D.:	340 ppm or 7 lbs/day

City Packing Co., 1931 S. 96th., Seattle - - - The kill at the City Packing Co. averages about 60 beef, 10 veal, and 25 lambs per day. Paunch manure is screened from the waste water, blood is collected and dried, and a trap is used to separate grease. Liquid wastes are discharged to the Duwamish. On the day of survey, November 22, 1955, 80 head of beef were processed.

Water usage:	40,900 gals/day
B.O.D.:	1,560 ppm or 178 lbs/day
S. S.:	1,434 ppm
T. S.:	2,220 ppm

Other industries located in proximity to the Green-Duwamish River but not surveyed are:

Pankratz Lumber Co., 2401 S. 98th St., Seattle - - - Wood wastes are handled in such a manner so as to prevent accidental spillage into the Duwamish. Sanitary wastes are treated in a septic tank-drainfield system.

Pacific Rendering Co., 9777 E. Marginal Way, Seattle - - - Meat scraps only are rendered at this plant, and the liquid waste is negligible insofar as BOD and solids are concerned. Visual observation indicates that grease was being effectively removed by a large grease trap and, since dead stock is not processed, the waste is insignificant.

Fisher Flouring Mills, Harbor Island, Seattle - - - Since this plant is in the process of removing some wheat washers and installing screening devices to process the waste waters from the remaining washers, a survey was not made. However, in addition to industrial waste, sanitary sewage from 450 employees is discharged directly to the Duwamish without treatment.

Sewage Treatment Plants

Following are the results of efficiency studies made on the three sewage treatment plants discharging to the Green-Duwamish River.

Auburn:

Date of Survey:	December 28, 1954
B.O.D. (Effluent):	180 ppm; 1200 lbs/day
S. S. " :	48 ppm
Percent Reduction BOD :	3.6%
" " S.S.:	10.0%

Date of Survey:	August 25, 1955
B.O.D. (Effluent):	145 ppm; 735 lbs/day
S. S. " :	57 ppm
Percent Reduction B.O.D.:	32.8%
" " S. S.:	54.4%

Kent:

Date of Survey:		August 18, 1955
B.O.D. (Effluent):		46 ppm; 882 lbs/day
S. S. " :		52 ppm
Percent Reduction,	B.O.D.:	78%
" "	S. S.:	65.1%

Oregon St., Seattle

Date of Survey:		September 1, 1955
B.O.D. (Effluent):		74 ppm; 2703 lbs/day
S. S. " :		53 ppm
Percent Reduction,	B.O.D.:	27.4%
" "	S. S. :	57.9%

From the above studies, it appears that the Auburn sewage treatment plant lacks sufficient capacity and should employ a higher degree of treatment in order to produce a satisfactory effluent. The Kent plant, on the other hand, produced an effluent with adequate B.O.D. and suspended solids reduction, even though the survey was made during the height of the cannery load. Results of the survey at the Oregon Street plant indicated the need for greater plant capacity to handle the volume of sewage.

Seattle Sewer Outfalls

In essentially any river discharging to salt water the most critical section is usually the estuary portion. Wastes discharged to an estuary tend to oscillate up and down river due to tidal action. Thus an organic waste can exert the maximum amount of oxygen demand before reaching salt water.

The greatest amount of raw sewage discharged to the Duwamish comes from the numerous outfalls and storm overflows of the Seattle sewer system. (See Figure 1). Those outfalls discharging along the west bank of the Duwamish were gaged as to flow and composite samples were collected and analyzed. Following are the results of surveys made on the five outfalls:

Street	Dia. of Outfall	Flow* Gals/Day	ppm B.O.D.	ppm S.S.	Lbs/day B.O.D.*	Population Equivalent
10th Ave. So.	42 in.	243,000	140	40	332	1,990
8th Ave. So.	42 in.	551,000	81	79	244	1,460
Highland Drive	18 in.	1,900,000**	75	214	790	4,730
W. Spokane St.	15 in.	159,000	100	78	70	420
Chelan Ave.	30 in.	395,000	227	133	748	4,480
						13,080

* Computed on basis of accepted standard hourly variation of flows and B.O.D
** Sampled after a rainfall - includes rain water

On the east bank of the river, the following sewers discharge directly to the Duwamish.

W. Stacy Street - - - 15 inch
W. Lander Street - - 90 inch
Hanford Street - - - 100 inch x 150 inch

Due to the difficulty in gaging and sampling these sewers, it was impossible to calculate the flow and strength of sewage. However, it can be safely assumed that the Lander and Hanford streets sewers contribute a very significant volume of raw sewage to the Duwamish.

In addition to the outfalls, there are four overflow structures which discharge a combination of raw sewage and storm water during periods when the capacity of the Marginal Way interceptor is exceeded.

RESULTS OF STUDIES ON TOXICITY

As mentioned previously, the Green-Duwamish River is affected by bacteriological contamination, reduction in dissolved oxygen concentrations and introduction of toxicants. Several industries located on the lower Duwamish discharge wastes containing toxic elements. As mentioned previously, essentially all of these toxic compounds are normally in sufficiently small concentrations as to be harmless to fish and other aquatic life. The danger lies in the accidental or careless spills which result in a "slug" discharge. These slugs of highly toxic properties can and have been extremely detrimental to aquatic life of the river.

Following is a brief discussion of each industry located on the Duwamish which discharges wastes containing toxic elements:

Boeing Airplane Co., Seattle - - - Toxic wastes from Boeings consist primarily of cyanides and chromates. Both are quite toxic to aquatic life and effluent standards established by the Pollution Control Commission are 0.5 ppm for cyanide and 10 ppm for chromates. Boeing accomplishes this by means of diluting toxic wastes with Green River water until concentrations are well below the prescribed limits. However, daily tests conducted by Boeing over a period of years indicates that there have been several occasions when concentrations of either cyanide or chromate were above the established limit and in the lethal range. These violations were due to leaks, accidental spills, etc., but their continued occurrence indicates that a more satisfactory method of controlling toxic waste concentrations is necessary.

Bethlehem Steel Corp., 8501 E. Marginal Way, Seattle - - - This industry fabricates and galvanizes steel, and wastes consist of acid pickling liquor which is hauled away for land disposal, and caustic wash water which is discharged to the river. It is essential that neutralization of the caustic wash takes place before discharge.

National Steel Construction Co., 500 Myrtle St., Seattle - - - Waste from the manufacture of hot water tanks, boilers, etc., consists of acid pickling liquor. At the present time, waste acid is discharged to the river untreated. Neutralization of the acid must be employed prior to discharge.

Kenworth Motor Truck Corp., 8801 E. Marginal Way, Seattle - - - Caustic wash water, acid and oil comprise the liquid wastes from Kenworth. Acid is disposed of on land, and the caustic wash receives a 15 to 1 dilution before discharge. However, an oil separator is needed at this plant to keep excessive oil from entering the storm sewer which ultimately discharges to the Duwamish.

Rheem Manufacturing Co., 3693 E. Marginal Way, Seattle - - - Rheem manufactures hot water tanks and heaters, and liquid waste consists essentially of acid pickling liquor at the rate of 4000 gallons per month. The liquor is neutralized with soda ash prior to discharge to the Duwamish. This method of waste disposal appears to be satisfactory.

A & B Barrel Co., 8604 Dallas Ave., Seattle - - - In the reconditioning and repainting of used barrels and drums, the A & B Barrel Co. uses about one ton per month of sodium hydroxide as a cleaning agent. Liquid waste, including oils, grease and sodium hydroxide is discharged to a small pond and thence to the Duwamish. An analysis of the waste revealed a concentration of 940 ppm NaOH, which in itself, is toxic to aquatic life. Dilution with river water would reduce concentrations to safe levels, but there is undoubtedly a lethal zone in the immediate vicinity of the outfall. Correction should be made either by dilution, neutralization, chemical recovery, or some other adequate waste treatment method.

Northwest Cooperage Co., 7152 1st Ave. So., Seattle - - - The Northwest Cooperage Co. is similar in operation to the A & B Barrel Co., but several times larger. Sodium hydroxide is the principal toxic waste discharged at this plant. Since the outfall sewer is located under a pier, it was impossible to obtain samples of the waste. However, on a comparative basis with findings at the A & B Barrel Co., it would appear that a similar zone of toxicity of larger dimensions exists around the point of discharge. Some procedure of correction should also be established at this plant.

Reichhold Chemical Co., 5900 W. Marginal Way, Seattle - - - The Reichhold plant at Seattle manufactures synthetic resins, formaldehyde, pentachlorophenols and hydrochloric acid. Toxic elements in the liquid waste consist of phenols and pentachlorophenols. During the summer of 1955, live box experiments conducted by the Department of Fisheries revealed highly toxic conditions existing in the vicinities of the outfall sewers on several occasions. The occurrence of these conditions of toxicity coincided with accidental slug discharges within the industry. Immediate corrective action was taken by the industry in the form of a temporary settling basin where toxic elements could be neutralized before discharge. Conditions will be further alleviated here when Reichhold moves its pentachlorophenol plant to a new location elsewhere in the State.

Western Oxygen Co., Harbor Island, Seattle - - - Waste from this concern consists principally of acetylene sludge which is deposited on the river bank adjacent to the industry. The sludge deposit tends to spill down the bank and into the Duwamish. Provisions must be made to haul all solid waste away for land disposal.

Todd Shipyards, Puget Sound Bridge & Dredging Co., Harbor Island, Seattle - - - These two concerns have no regular toxic waste, but occasional oil spills have occurred during ship repair operations, etc. Recently the Puget Sound Bridge and Dredging Co., have instigated a program of treating the interiors of drydock pontoons with arsenic to kill infestations of marine borers. The discharge of the dilute arsenic solution is done under the careful surveillance of representatives from the Pollution Control Commission and the Fisheries Department and as yet, there have not been any noticeable deleterious effects.

American Marietta Co., Harbor Island, Seattle - - - Products manufactured by American Marietta are soy bean and protein glues, urea formaldehyde resin and phenol-formaldehyde resin. Liquid wastes are discharged via a city sewer to the Duwamish and are essentially kettle wash and rinse waters. Toxic elements in the waste are phenol-formaldehyde and urea-formaldehyde (up to 5000 ppm) and sodium hydroxide (up to 10,000 ppm). At such concentrations, these compounds are extremely toxic. A further investigation will be made to determine the recovery or treatment necessary.

West Coast Wood Preserving Co., 27th S.W. & W. Florida, Seattle - - Although highly toxic preserving compounds, such as sodium arsenate, are used at this plant, the wood preserving operation is a closed system and only by accident could toxicants enter the waterway.

WATER MANAGEMENT

As noted previously in this report, there are several uses of Green River waters: domestic water supply, industrial water supply, irrigation, fisheries and pollution abatement. These diversified uses can all be satisfied, but only by careful water management practices. The Green River is characterized by extensive variation in flow (maximum discharge at Auburn, 22,000 cfs, Dec. 11, 1946; minimum, 81 cfs, Sept. 23, 1952), and it is during the low flow periods that shortages can occur and have occurred.

Eagle Gorge Dam

In 1949, the Chief of Engineers, United States Army, presented a plan of development for the Green River basin in the interests of flood control, fish conservation, pollution abatement, domestic water supply and irrigation. The plan called for the construction of a dam and reservoir at the Eagle Gorge site, approximately one mile below the confluence of the Green River proper and the North Fork. With a maximum height of about 230 feet above the stream bed and a crest length of 720 feet, the proposed dam will have a gross storage of 106,000 acre feet.

In the interest of flood control the Corps of Engineers proposes to keep the reservoir empty from November 1 to February 1 each year except for temporary impoundment of flood waters. Storage of 10,000 acre feet would be permitted in February and the filling would continue during March, April, May and June. Subsequent releases could then be made during the dry summer and fall months for the benefit of water supply, pollution abatement and fish propagation. Controlled flood releases would not exceed 10,000 cubic feet per second.

At the present time, the first phase of construction is underway with the relocation of the Northern Pacific Railway facilities in the Eagle Gorge area.

Present and Potential Water Uses

The present policy of the Corps of Engineers is essentially as follows:

1. The dam is essentially a flood control project to be operated in a manner to provide protection against the maximum anticipated runoff expected in any 100-year period.

2. A sustained release of 400 cfs is possible at no impairment to the flood control features of the dam.

3. The present plan for summertime releases of water is at a rate of 110 cfs for fisheries habitat plus the natural river flow, with the total release being about 220 cfs at minimum flows.

4. At such time as the City of Tacoma may require stored water, it could be made available after determination of a reasonable fee by the Secretary of the Army and in accordance with the policy set forth in section 6 of the Flood Control Act approved December 22, 1944. Similarly, the use of stored water for irrigation would be provided upon payment of a reasonable fee to the United States when the region may become organized for irrigation development under the Federal Reclamation Law.

Following is a comparison of the supply to be made available and the existing and future needs in the lower river:

Use	Present Needs	Future Needs
Tacoma Water Supply	110 cfs	220 cfs
Fisheries Habitat and Pollution Abatement	200	200
Irrigation	17 +	113
Industrial	4	4 +
	341 +	537 +

The available minimum supply is about 220 cfs (item 3 above) plus a minimum of 60 cfs., (contributions of tributaries from below the dam to just above Soos Creek) or a total of 280 cfs. Thus, there will be a possible deficit of 61 cfs during extreme low flows when future demands become realities.

Superimposed on the Green River discharge graph (Figure 3) are D.O. and temperature values for samples collected at Station 10. Correlation between flow and D.O. concentrations is quite apparent, and indicates the necessity for adequate flows during the late summer and fall months in order to maintain satisfactory oxygen conditions.

Tacoma has an application for an additional 100 second feet, presumably to protect its interests against any water appropriation for downstream power development. However, the City of Tacoma plans to move its present water intake structure 2000 feet downstream since it does not operate properly during high water flows. The new intake will have enough capacity to handle 200 + second feet. It appears that sometime in the future, Tacoma's water requirements will necessitate the acquiring of the additional 100 second feet.

In view of the increasing agriculture, industrial and municipal demands of Green River water, it appears certain that flow deficits will exist in the lower river during dry years if the present plan of release of stored waters is used.