A BASELINE STUDY OF THE WATER QUALITY, SEDIMENTS, AND BIOTA OF LAKE UNION

by

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Municipality of METROpolitan Seattle

March, 1977

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ACKNOWLEDGMENTS

The successful planning, execution, and reporting of this study depended heavily on many individuals whose names do not appear on the title page. Without the talents and knowledge of these individuals, this document would have been considerably less comprehensive; the authors gratefully acknowledge their effort, information, and suggestions.

Municipality of Metropolitan Seattle - Jean P. Alexander, Brian N. Bebee, Robert N. Brenner, John M. Buffo, Karen B. Clark, Edward O. Cox, Raymond D. Dalseg, Carolyn H. Erickson, Glen D. Farris, Donald W. Gleason, Martin E. Harper, Douglas A. Hilderbrand, R. Wesley Hopkins, Paul D. Houston, Cynthia C. Jaegar, Esther Laband, Jean H. Lewis, Spencer Louthan, Michael W. Mar, Cille V. Monson, William E. Nitz, Linda M. Odegard, Debbie S. Potter, Darrell S. Prentice, Susan M. Pryor, Richard H. Putney, Angelita Santa Maria, Stanley S. Saxton, Robert G. Swartz, David L. Todd, Barry K. Uchida, N. Rocky Wells, Cecil M. Whitmore.

City of Seattle Engineering Department - Patricia A. Flynn, Keith A. Harris.

Milmanco, Inc. - Frank J. Ernest.

Puget Sound Air Pollution Control Agency - K. Boyd Knechtel.

University of Washington - Eugene E. Collias, W. T. Edmondson, William R. Schell, Allyn H. Seymour, Dimitris E. Spyridakis, Eugene B. Welch.

U. S. Army Corps of Engineers - Byron Esko, Arthur J. Ficken.

U. S. Environmental Protection Agency, Dist. X - Ronald A. Kreizenbeck.

U. S. Geological Survey - William W. Clique, David W. Thompson.

Contributing Citizen - Charles R. Hitz.

Cover Photo - F. Shaver

1. INTRODUCTION

Lake Union is an inland, freshwater lake located in the heart of the City of Seattle, To the northwest, it is connected to Puget Sound via the Fremont cut of the Lake Washington Ship Canal (see Fig. D-1). To the northeast it is joined to Portage Bay, whose waters mix with those of Union Bay and Lake Washington through the Montlake cut.

The Montlake channel was completed in 1916 as part of a plan to promote better flushing of Lake Washington and simultaneously provide a navigable waterway between Lake Washington and the Sound. As part of the plan, the Cedar River was diverted to the southern end of Lake Washington, and the Hiram M. Chittenden Locks were constructed at the mouth of Salmon Bay.

Today, this interconnected system of lakes and channels is a much utilized passageway and recreational area. Numerous commercial and pleasure craft ply its waters and are moored along its shores. Particularly in Lake Union, marinas, houseboats, and commercial docks abound; extensive moorage and drydock facilities of the West Coast fleet of the National Oceanic and Atmospheric Administration occupy its southeastern shore.

Before regulation was implemented, the spillage and disposal of fuel, paint, bilge, and human wastes from such craft greatly accelerated the deterioration of the lake.

The area immediately surrounding the lake is heavily industrialized. A 1943 report (Foster, 1943) published by the Washington State Pollution Commission listed 45 industries on the shores of Lake Union and the Lake Washington Ship Canal, in addition to the previously mentioned marinas and boatyards (20 of which were listed as sources of pollution). These included 10 machine shops and metal foundaries; 10 lumber and plywood mills; 12 fuel and oil storage and service facilities; 8 companies dealing in sand, gravel, concrete or asphalt; the Seattle City Light Power Plant on the southeastern shore; and the Seattle Gas Plant on the northern shore. The last-mentioned establishment was listed as one of the worst sources of lake water pollution, routinely discharging oily wastes through inadequate filters and occasionally spilling large quantities of oil so that the surface of the water was covered and fish were killed in its vicinity. Today, it is no longer in operation, having been turned over to the city in 1963 for conversion to a public park.

The industrial composition has changed little in the past 32 years. Indeed, a large fraction of the establishments listed in the 1943 report are still operating, although

increasingly stringent pollution regulations have undoubtedly decreased individual discharge levels.

Sewage and storm drainage has also been a significant source of pollution to Lake Union in recent history. At the time of the report cited above (Foster, 1943), ten combined overflows dumped wastewater into Lake Union between the University and Fremont Bridges. Since that time, seven storm drains and nine emergency overflows have been added to the system. Five of the storm drains carry runoff from up to 250 acres of Interstate Highway 5, which runs along the eastern side of the lake. Also, most of the residences and commercial establishments and up to 200 houseboats lining the shores of Lake Union originally had direct sewage outfalls entering the lake. Those were intercepted by the City of Seattle in 1963.

Atmospheric fallout is also an important potential source of pollution to the waters of Lake Union. Studies in nearby Lake Washington (Barnes and Schell, 1973; Crecelius and Piper, 1973) indicated up to sixteenfold increases in sediment lead concentrations since 1890. The buildup was attributed predominantly to automobile exhaust and smelter stack emissions. The studies also showed fourfold zinc and copper increases for the same period. The atmospheric inputs for these two metals were estimated at 68 percent and 56 percent of the total, respectively.

Finally, it should be mentioned that Lake Union has not entirely escaped the despoiling inconsideration of environmentally oblivious citizens. Over the years it has received a significant load of miscellaneous castoff waste, which probably has affected only a little of its present level of water quality but has detracted considerably from its aesthetic value.

2. PURPOSE AND SCOPE

GENERAL

In less than a century, Lake Union and its surroundings have been transformed remarkably (Figs. 2-1 through 2-5). In 1890 the lake shores were partially wooded and sparsely settled. Sawmills were in operation on the northeastern, northwestern, and southern banks. Today a large portion of the basin is paved with concrete and asphalt, and the shores are lined with boats and buildings. No longer an isolated body of water, Lake Union is now part of a busy inland waterway, traversed by traffic between Lake Washington and Puget Sound. The air over the lake has contaminants far more sinister than wood smoke.

The overall threat to the natural and aesthetic aspects of Lake Union has therefore multiplied considerably. Numerous civic groups and private citizens are alarmed that the deterioration may increase and ultimately result in its ecological destruction if not checked. Necessary to any improvement projects is an evaluation of present conditions, a baseline water quality data bank. At the request of the City of Seattle Department of Community Development, Metro in 1974 undertook a one-year study to assess the quality of the water, sediments, and biota. This report is a summary and discussion of the results of that study.

Several specific questions served as a guide for the planning and development of the Lake Union Study:

1) What is the present quality of the water and sediments?

2) What is the present condition of the phytoplankton and benthic communities?

3) What is the present trophic state of the lake?

4) What is the effect of the saltwater intrusion (from the Chittenden Locks) on all of the above?

5) How do the sediment conditions of Lake Union compare with those of other local bodies of water?

The parameters selected for measurement on the basis of these questions are listed in Table 2-1. A complete set of samples for measurements in Part I of the table was taken at each of four stations (see Fig. 2-6) at semimonthly intervals from January 3 through December 26, 1974. Sediment measurements (Section 5) were made on either two or three occasions during the study, depending on the parameter. These samples were taken on February 7, September 20, and December 18. Measurements for Part III of Table 2-1 were obtained from external sources; these are given with the data.

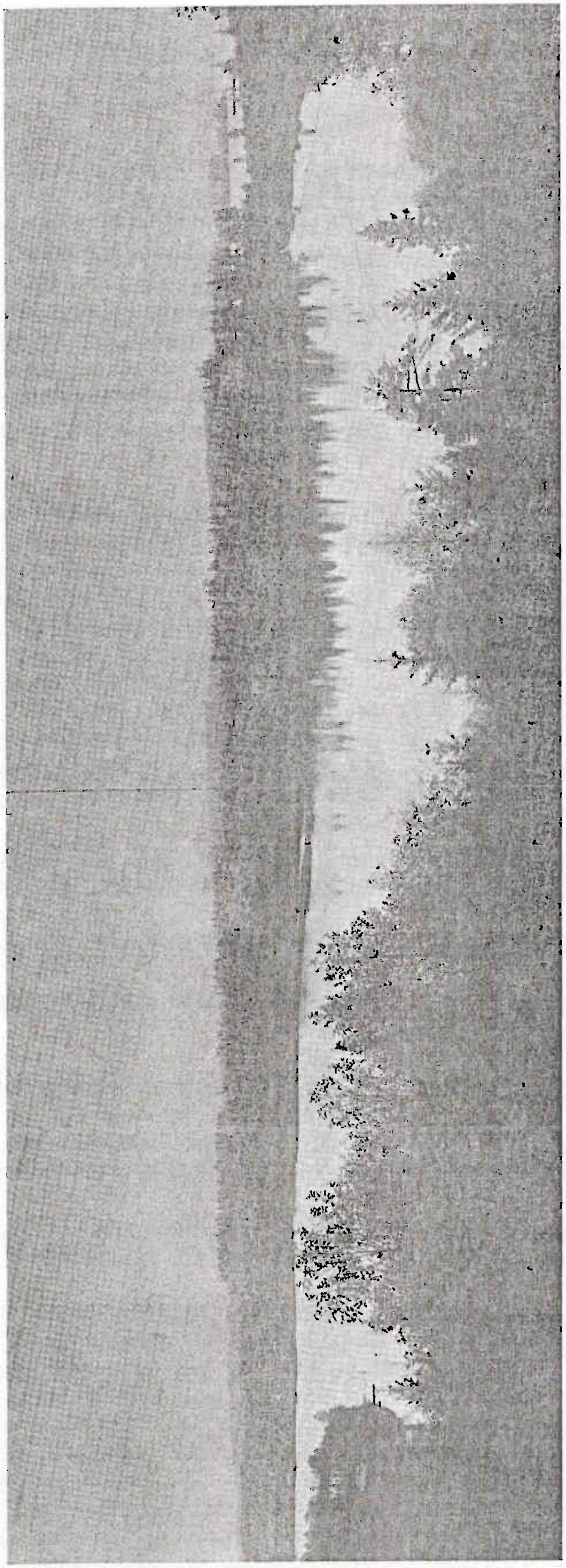


Fig. 2-1. Panorama of Portage Bay and Montlake from the southwestern shore, ca. 1907 (Photographer unknown, Univ. Wash. Suzzallo Lib. Photog. Coll.).

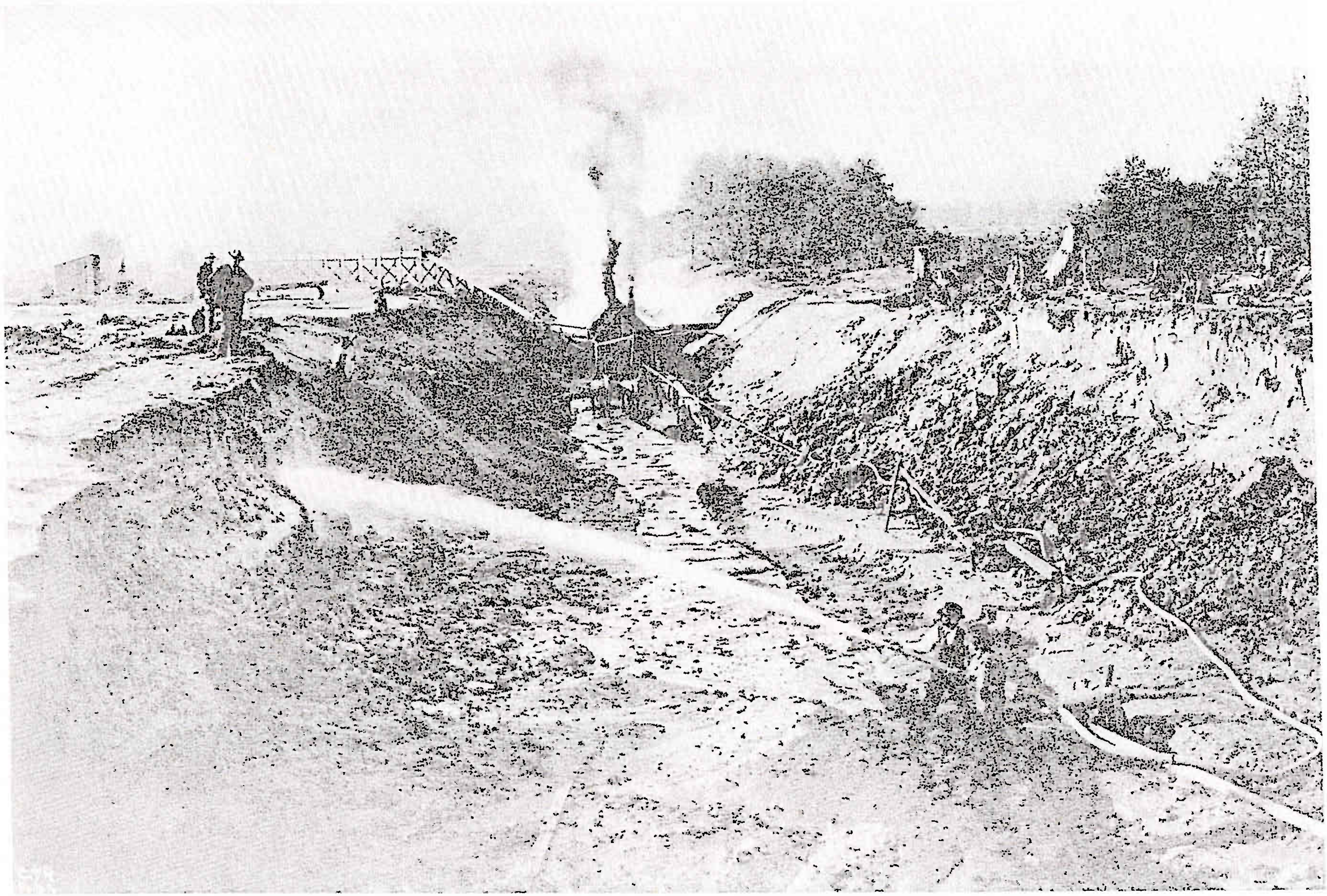
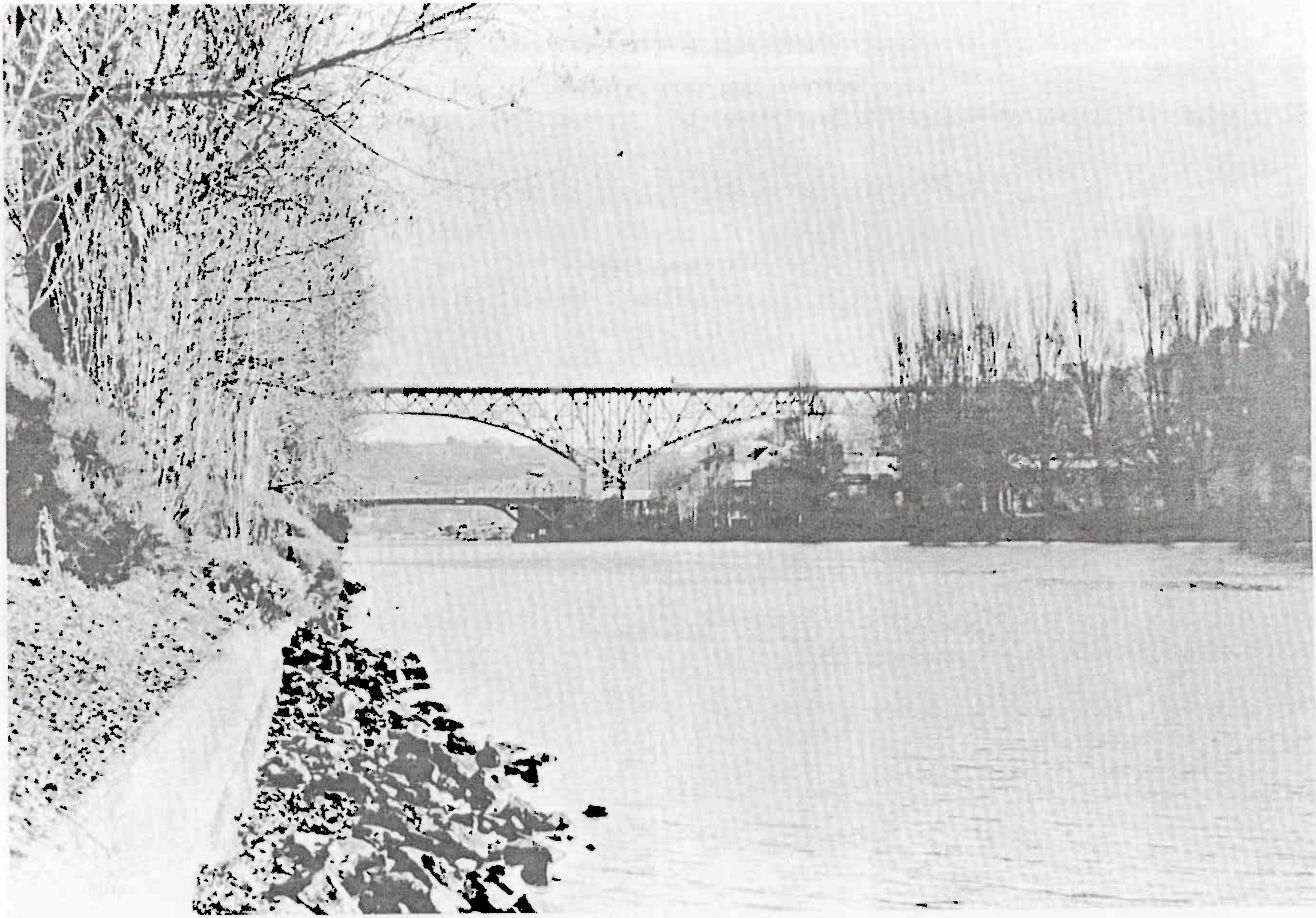


Fig. 2-2 (a). The Fremont Channel, 1906 (A. Curtis, Ibid.).



(b.). The Fremont Channel, 1974 (R. D. Tomlinson).

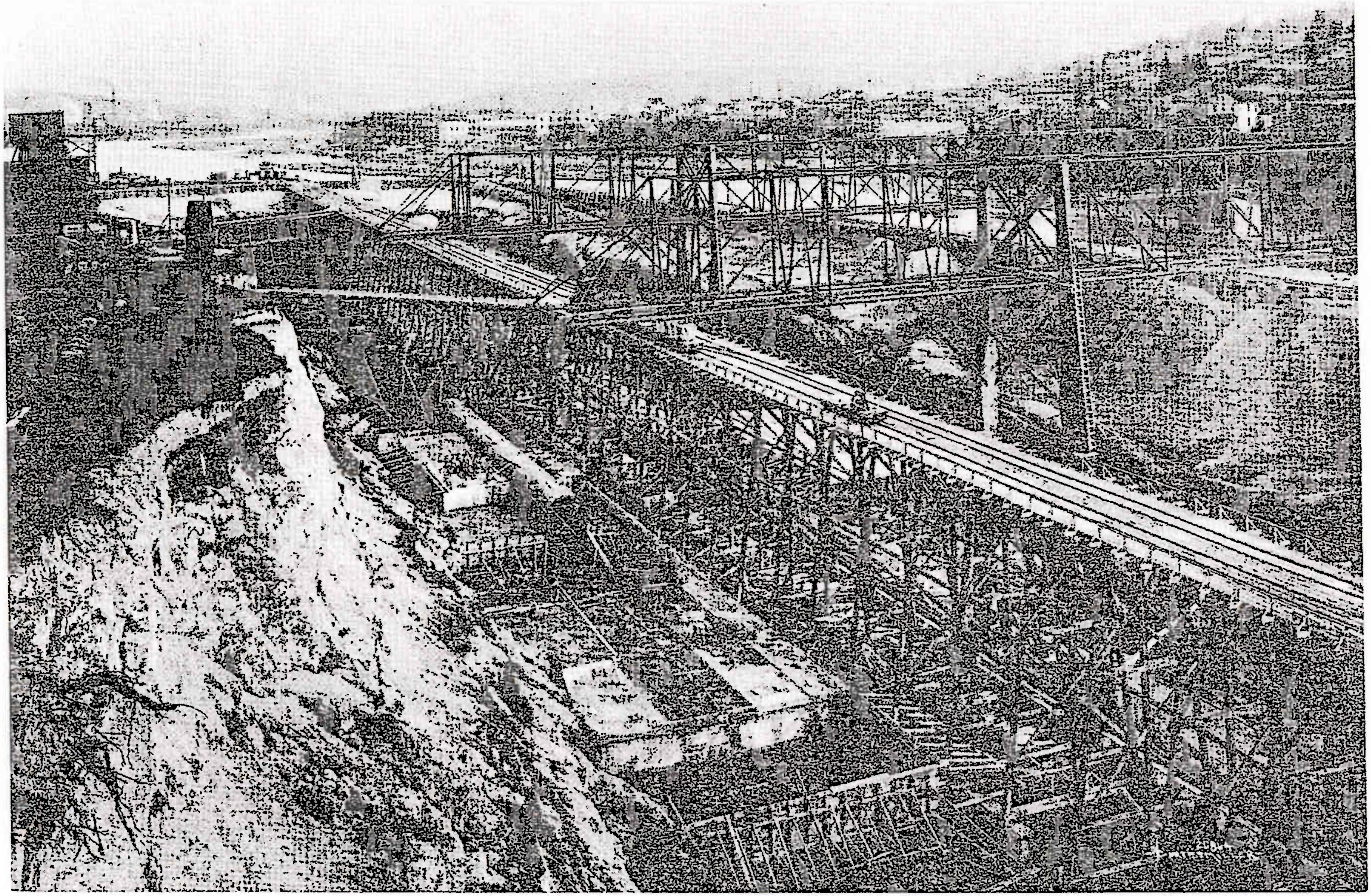


Fig. 2-3. Salmon Bay and the U.S. Government Locks, 1913 (A. Curtis, Univ. Wash. Suzzallo Lib. Photog. Coll.).

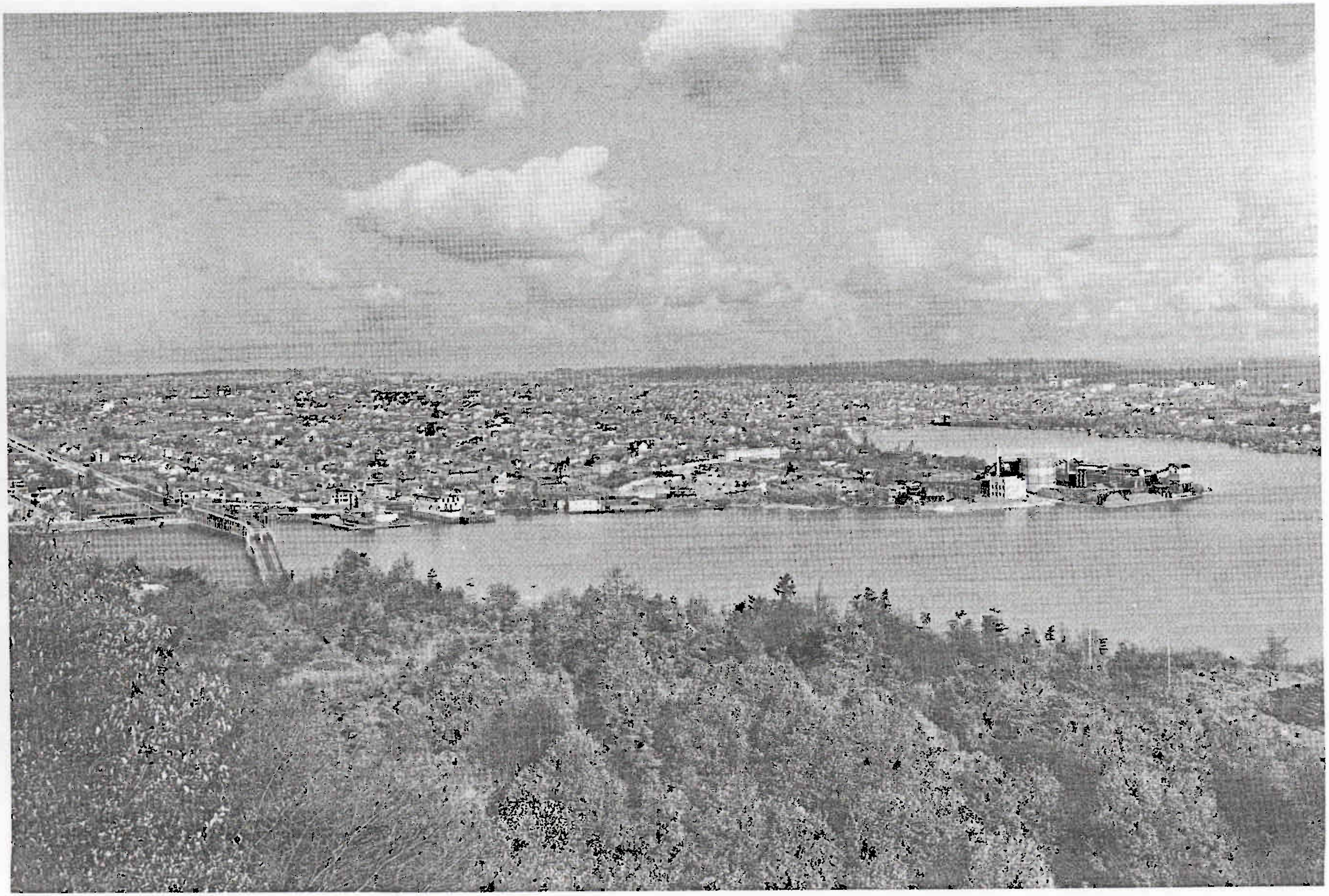
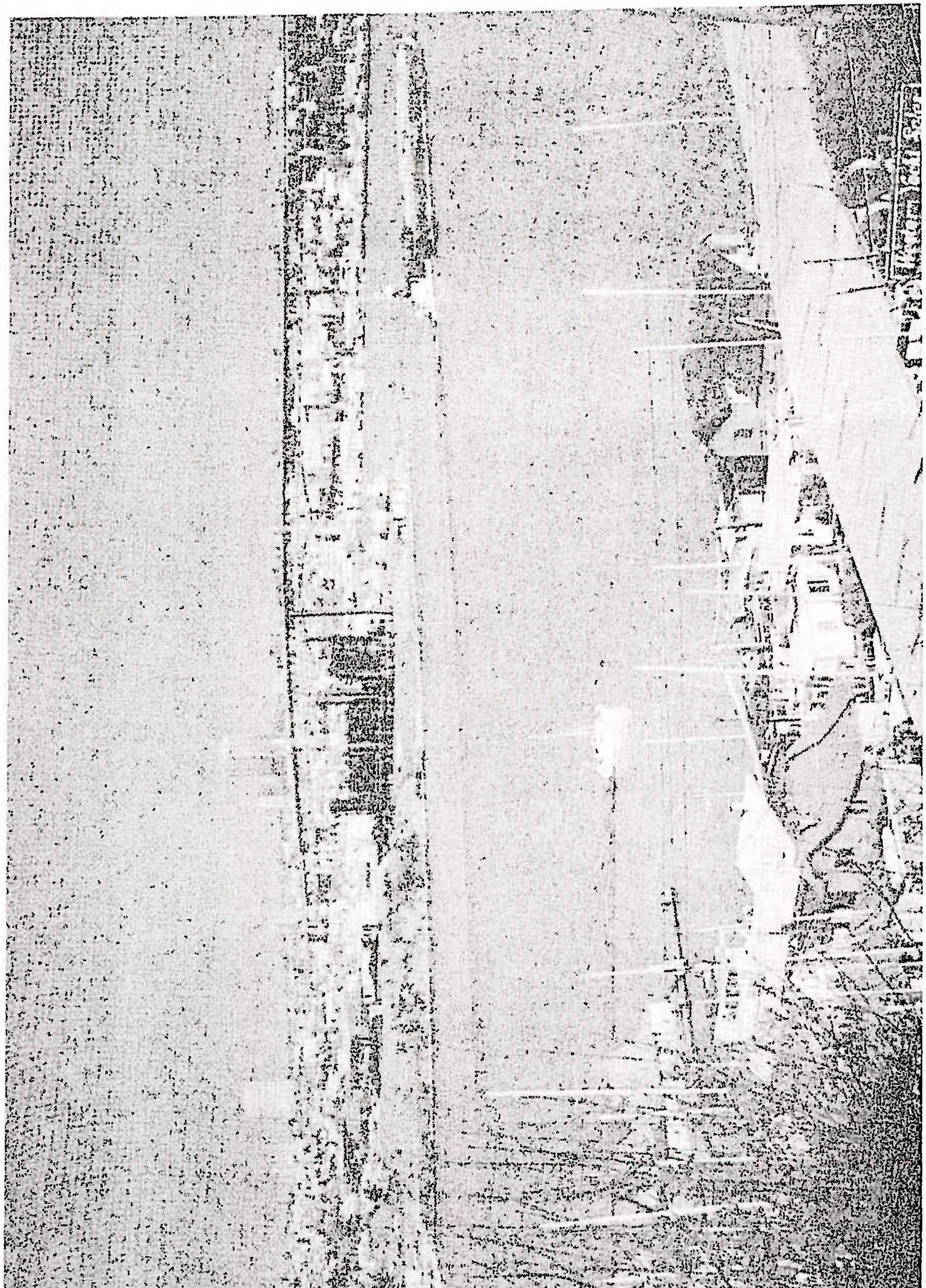
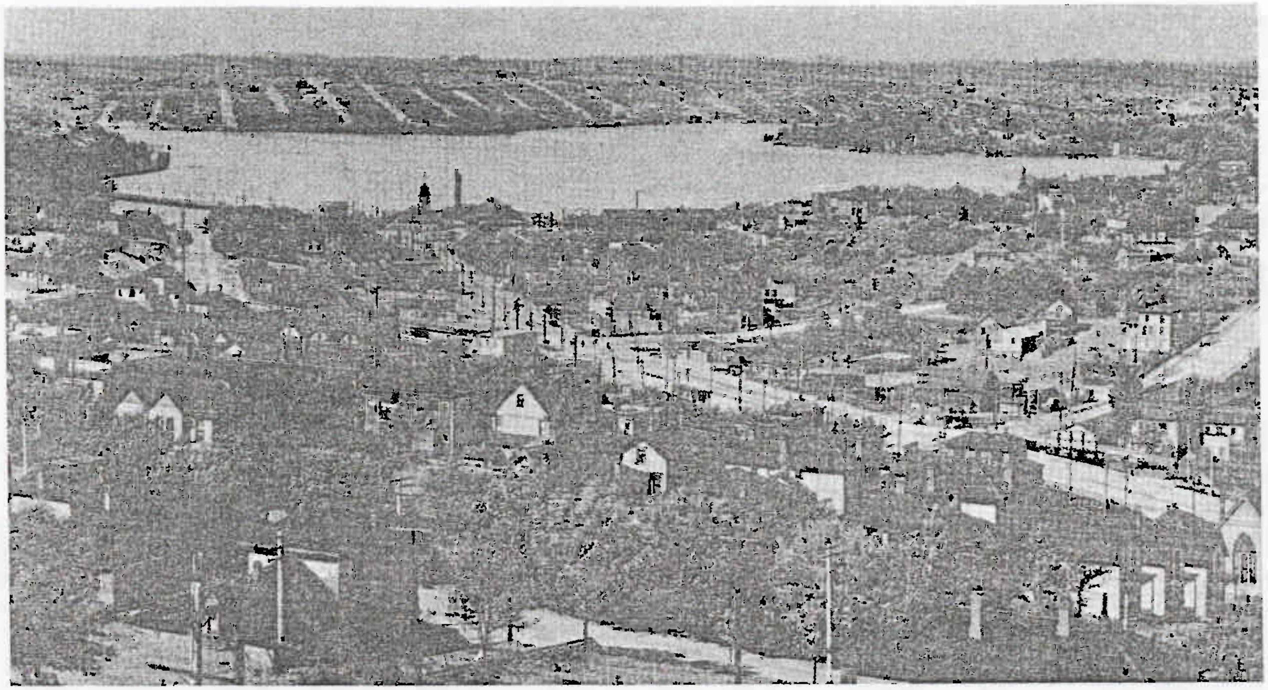


Fig. 2-4 (a). Northwestern Lake Union, 1915 (C. F. Todd, Ibid.).

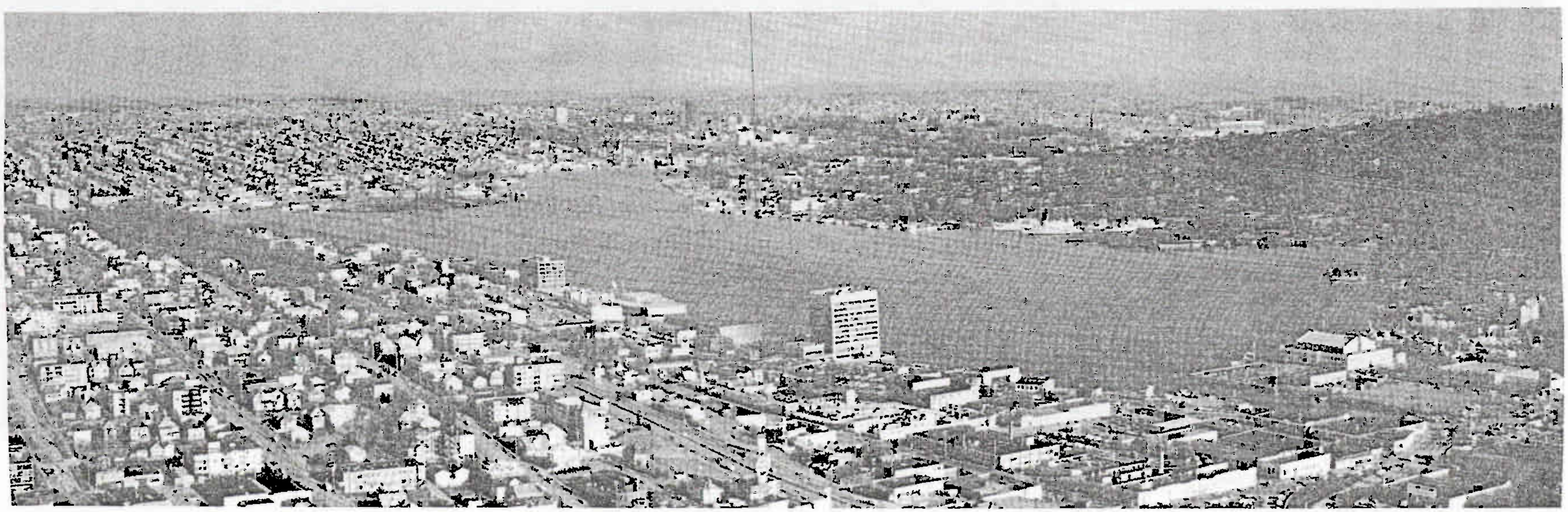


(b.) Northwestern Lake Union, 1974 (R. D. Tomlinson).

Fig. 2-5 Lake Union.



a). Ca. 1906 (Photographer unknown, Univ. Wash. Suzzallo Lib. Photog. Coll.).



b). 1974 (S. Louthan).

TABLE 2-1. List of Parameters

I. Water Column
  A. Physical
    1. Salinity/conductivity
    2. Temperature
    3. Dissolved Oxygen
    4. Turbidity/Suspended Solids

  B. Chemical
    1. Nutrients
      a. $NO_3 + NO_2$
      b. NH_3
      c. Ortho PO_4
      d. Total Hydrolyzable PO_4

    2. Metals
      a. Lead
      b. Zinc
      c. Copper
      d. Chromium
      e. Nickel
      f. Cadmium

    3. pH/Alk.

    4. Hardness ($CaCO_3$)

  C. Biological
    1. Chlorophyll a
    2. Algal Volume Density
    3. Algal Species Composition
    4. % O_2 Saturation
    5. Secchi
    6. Coliforms
      a. Total Coliforms
      b. Fecal Coliforms
    7. BOD
    8. Zooplankton Species Indentification*

II. Sediments
  A. Chemical
    1. Nutrients
      a. Total Kjeldahl
      b. Soluble Total Kjeldahl
      c. NH_3
      d. Total PO_4
      e. Soluble Total PO_4

    2. Metals**
      a. Lead
      b. Zind
      c. Copper
      d. Chromium
      e. Nickel
      f. Cadmium

3. COD

4. Total Volatile Solids

5. Oils and Greases
    a. Total Concentration
    b. Polarization (% Petroleum/% Animal)

B. Biological
    1. Macrofaunal Species Identification

III. External Influences
    A. Natural
        1. Wind
        2. Precipitation
        3. Incident Solar Radiation

    B. Anthropogenic
        1. Frequency of Locks Operation
        2. Incidence of Sewer Overflows

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* Includes data from one sampling at Station 522, done 9/18/75

** Includes core profiles and sediment dating

With the exception of sediment dating, all analyses were done in the Metro Water Quality Laboratory in accordance with the methods specified in Appendix A of this report. Sediment dating was carried out at the College of Fisheries Laboratory of Radiation Ecology at the University of Washington under the direction of Dr. W. R. Schell. The sediment dating was done by the ^{210}Po - ^{210}Pb method, also detailed in Appendix A.

SELECTION OF SAMPLING SITES

The four sampling sites (Figs. 2-6 and D-1) were selected on the basis of lake bathymetry and circulation. A brief review here of the information available on these subjects will help put into perspective the process of selection and much of the discussion of the data to come later.

The water circulation in Lake Union is very complex. Rhodamine B studies by Driggers (1964) during October, 1963, indicated a general movement of water at 12.5 m depth approximately parallel to the long axis of the lake. Thus, dye injected midway between the locations of Metro Stations 526 and 532 (Fig. 2-6) moved southward to a position due east of Station 522 over a period of 10 days. During this period, plumes of dye also streamed into the northern waterway, first moving beyond the Fremont sill (3 days elapsed time), and then spreading toward the northeast and the Montlake cut (6 to 7 days elapsed time). The maximum rate of northerly dye advection during the study was 4.7 m/h, whereas that to the south was measured at 8.9 m/h.

The circulation pattern described by Driggers is not entirely in keeping with that observed by CH_2M/Hill (Layton, 1975) during October of 1973. The prevailing circulation was found to be the movement of water from Lake Washington through Lake Union to Puget Sound, with temporary reversals of the flow between the two lakes. A drogue was set to follow currents at 12.2 m depth and released just north of Metro Station 526; it moved toward the NE at the rate of 18 m/h. A surface dye patch was advected in the same direction at the rate of 84 m/h. The rate of flow through the system at this time was only 6 percent as great as that measured during Driggers' study in Oct. 1963. Layton suggested that wind-generated seiches in Lake Washington control currents in Lake Union through differences in hydraulic surface elevations.

The prevailing circulation through the Ship Canal and Lake Union is dictated by a number of conditions. The two most important influences are the amount of precipitation in the area drained by the canal and the number of lockages (Smith & Thompson, 1927). During the winter months there is heavy

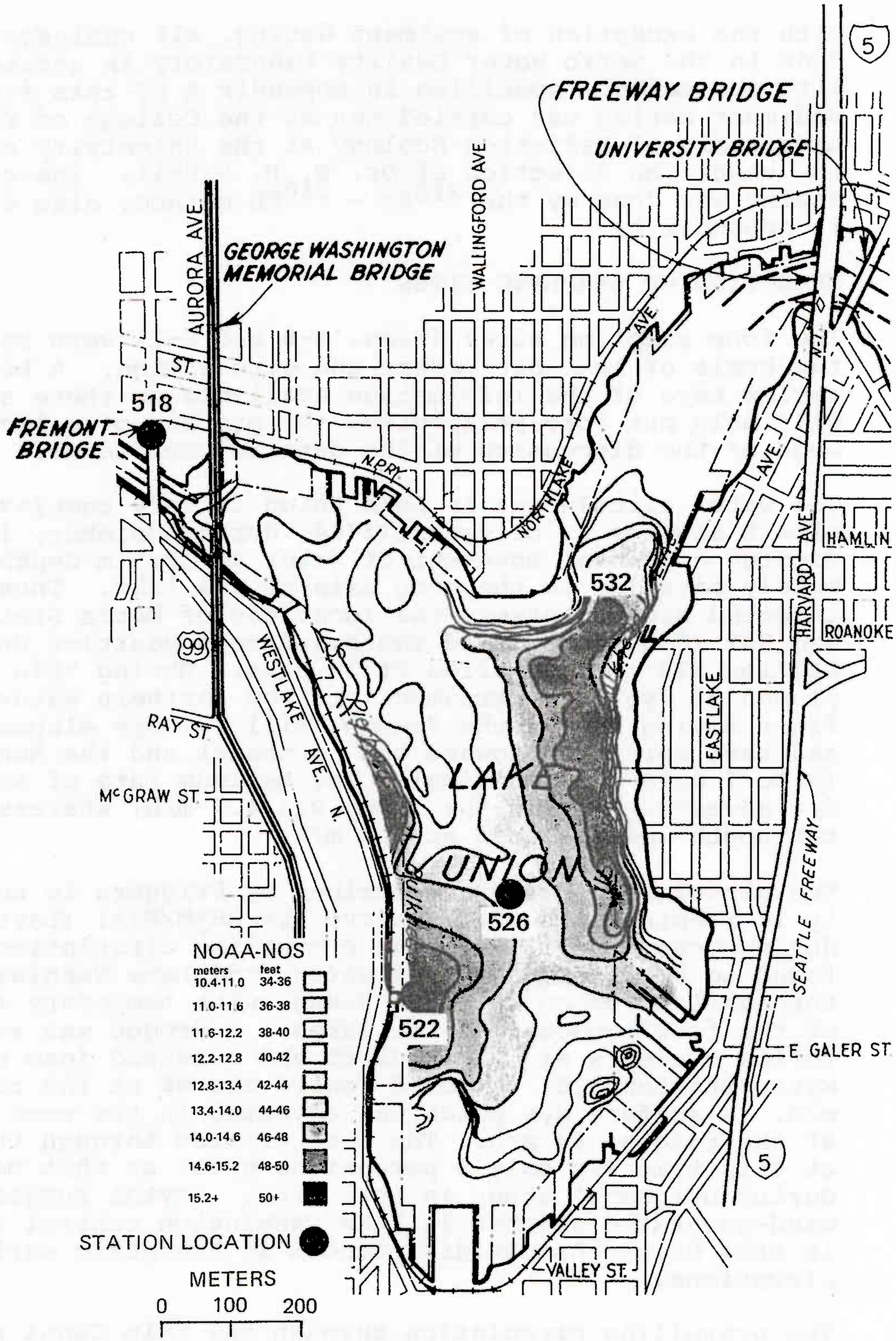

Fig. 2-6. Bathymetric contours and station locations (from NOAA-NOS Chart 18447).

precipitation throughout the region and a consequent maximum flow of water from Lake Washington through Lake Union and through the Chittenden Locks to Puget Sound. As the precipitation diminishes in the spring, snow melt in the upper reaches of the Cedar River and Lake Sammamish watersheds helps to sustain this flow.

The movement of water through the system drops by more than 90 percent during the comparatively dry summer months. During this time the opposing flow of brackish water from increased lock usage dominates the near-bottom circulation patterns. This saline water moves from the catch basin immediately above the locks through Salmon Bay and pours into the deeper regions of Lake Union. These two major opposing effects are enhanced or dampened by tides outside the locks and varying water densities.

On the basis of these findings, there appeared to be two major regions of interest for Metro's proposed work in Lake Union: the Lake Washington drainage channel through the northern end of the lake and the main body of Lake Union itself. An attempt was made therefore to select stations deemed representative of conditions in these two areas.

At the same time, several other criteria had to be met. Stations were needed to provide data characteristic of Lake Union's major inlet and outlet. At least one profile station was desired, in a deep part of the lake. In addition, a midlake location was sought that would receive a minimum of shore structure interference with wind and light and also a limited influence from sewer overflows or other anthropogenic effluents and contamination.

Ultimately, four stations were selected to fill these needs. Their locations and the associated bottom topographies are detailed in Fig. 2-6. Stations 518 and 532 were located in the channel, and represented the major lake inlet and outlet (which are perhaps somewhat interchangeable, depending on the prevailing wind conditions). Station 532 was situated at the end of a trench running along the eastern shore, so that it also served as a secondary profile station. The primary profile station was 522, a site also monitored during past studies. The midlake station was located in the center of a bathymetric saddle, with shallow areas to the northeast and southeast and maximum depths in the other two quadrants.

Stations 518 and 526 were sampled at the surface and near the bottom; Stations 522 and 532 were sampled at 5 m intervals between the surface and the bottom.

3. METHODS

The details and references for the field and laboratory methods used in this study are given in Appendix A.