PART VI

FINDINGS AND RECOMMENDATIONS

Chapter 20
SUMMARY OF FINDINGS

In the preceding chapters we have presented what has become a somewhat massive report, weighted down not only by a text containing many thousands of words but by numerous tables, charts and diagrams. As such, it can hardly be regarded as suitable for cover to cover reading and study. We are confident, however, that the information here recorded will be utilized for many years in solving sewerage and drainage problems of the metropolitan Seattle area.

Many of those who find it necessary to refer to this report will have neither the time nor the inclination to study it in detail. For their purposes, a summary is required which covers the essential facts and presents them in a manner which is both useful and readily understandable. This chapter has been prepared accordingly and reviews, as briefly as possible, the nature, magnitude, and scope of the recommended sewerage and drainage projects.

PART I. INTRODUCTION AND HISTORY

Residents of Seattle and surrounding communities are faced with long-standing sewerage and drainage problems which are becoming increasingly serious and which, if not resolved, will emerge as major obstacles to continued growth and development of the metropolitan area. Recognition of these problems and of the need for effective long-term solutions prompted city, county and state officials to join in sponsorship of the survey here reported. Part I summarizes major sewerage and drainage problems now confronting the metropolitan Seattle area. In addition, it sets forth the objectives and scope and the general procedures employed in making the survey, and presents a chronological history of sewerage developments and events.

Chapter 1. Introduction

1. The metropolitan Seattle area enjoys an abundance of diversified water resources. These range from fresh water inland lakes and streams to the saline waters of Puget Sound and are utilized intensively for a wide variety of recreational, industrial, commercial, agricultural and other purposes. They represent a community asset of inestimable value and as such must be protected against unreasonable impairment by sewage and industrial waste discharges.

2. Among the factors contributing to the sewerage and drainage problems of the area are:

a. Increased population. Long-term population estimates indicate that the metropolitan population will increase from the present total of 860,000 to about 1,250,000 by 1980 and to about 2,250,000 by 2030.

b. Discharges of untreated sewage. Sewage from 53 per cent of the present population is being discharged into environmental waters without treatment. As a result, recreational shore waters are subject to contamination, water quality is being impaired with respect to other beneficial uses, and nuisance conditions prevail at many locations.

c. Sewage overflows into recreational waters. In sewerage systems carrying both sanitary sewage and storm water, overflows occur at some locations nearly every time it rains.

d. Algal growths in Lake Washington. Lake Washington is being degraded as a result of algal growths, caused in part by the nutrient substances contained in sewage and sewage effluent discharges.

e. Sewage receiving capacity of Duwamish River. This river is approaching the limit of its capacity to receive putrescible substances.

f. Use of individual sewage disposal systems. About one-third of the metropolitan population is without public sewerage service. As a consequence, these people are compelled to rely on individual household sewage disposal systems, construction of which is being maintained at an average rate of about 6,000 per year. Many such systems are doomed to early failure because of the unfavorable soil drainage conditions which prevail in most of the area.

g. Overloading of combined sewers. Many of the combined sewers which serve the city of Seattle become grossly overloaded during periods of rainfall. Overloading causes frequent back-ups of sewage into basements and streets.

3. Physical and environmental factors require planning of sewerage and drainage facilities on a watershed rather than political boundary basis.

4. Present conditions in the metropolitan Seattle area reflect an urgent need for the development of a comprehensive, long-range program of sewerage and drainage improvements. Such a program must incorporate existing facilities to the fullest practicable extent and must have as its principal aim the protection of shores and shore waters from contamination, pollution and nuisance.

Chapter 2. History of Sewerage Problem

1. Sewers consisting of wood troughs were constructed in Seattle as early as 1865. The first permanent sewers were constructed in 1883.

2. In 1889, Colonel George E. Waring Jr., submitted a comprehensive plan calling for the construction of a separate system of sanitary sewers. After considerable controversy, the Waring plan was rejected in favor of a proposal submitted by Benezette Williams which recommended construction of combined sewers carrying both sanitary sewage and storm water.

3. Extensive sewerage works constructed in accordance with the Williams plan during the period from 1890 to 1914 still serve as principal elements of the Seattle system. One of the primary functions of these early sewers was to intercept dry weather flow from the Lake Union, Green Lake and Lake Washington drainage basins and to convey it through and around intervening ridges to the saline waters of Puget Sound.

4. As the city grew, the older systems were extended and numerous independent systems were constructed. By 1920, developed sections of the city were moderately well covered by a network of sewers.

5. Because no treatment facilities were provided and sewage outfalls usually terminated at the water's edge, hazards to health and nuisance conditions soon developed in many parts of the city.

6. Since 1920 repeated recommendations have been made to the effect that treatment should be provided and that the combined sewer systems should be either partially or completely separated.

7. Construction of the Lake Washington interceptor system between 1926 and 1936 eliminated raw sewage outfalls into the lake. Nevertheless, overflows of combined sewage still occur at some 30 points nearly every time it rains.

8. The Diagonal Avenue sewage treatment plant was constructed in 1940 and serves about one-sixth of the area connected to combined sewers. Sewage from the remainder of the combined system is still discharged without treatment.

9. Areas annexed to the city since 1954 included five sewer districts, each of which was served by separate sanitary sewer systems prior to annexation. These systems, which include four sewage treatment plants, have since been operated by the city.

10. In 1956, the Seattle electorate approved a $6.25 million bond issue for sewerage improvements. Adoption of a monthly sewer service charge was also approved at the same time. Funds thus made available resulted in the design and present construction of (1) an interceptor system and treatment works to serve West Seattle; (2) enlargements to the Lake City sewage treatment works; and (3) an interceptor along Shilshole Bay north of the ship canal.

11. Despite the fact that there now are 26 independent sewerage systems in operation within the metropolitan Seattle area, nearly one-third of the population is without public sewerage service.

PART II. CHARACTERISTICS OF THE METROPOLITAN SEATTLE AREA

The planning of comprehensive sewerage and drainage facilities requires as a background an adequate knowledge of environmental factors, both physical and economic. Part II deals with these factors, particularly as they relate to future growth and development of the metropolitan area.

Chapter 3. Physical Geography

1. Local geography, as defined by topography, geology, climate, natural and political boundaries, and water areas, influences in many ways the design, construction, cost and operation of sewerage and drainage works.

2. As used in this report, the metropolitan Seattle area extends from the vicinity of Silver Lake on the north to the city of Auburn on the south and from Puget Sound inland for a distance of 18 miles at the widest point. Containing 19 incorporated cities, it encompasses an area of about 575 square miles and includes, in addition to western King County, portions of both Snohomish and Pierce counties. Within the area are about 27,000 acres of inland water and some 140 miles of fresh water shoreline.

3. Topographically, the metropolitan area is comprised of striated hills, rolling glaciated uplands, and deeply incised adjoining troughs. Except for a prominent east-west ridge between the south end of Lake Washington and the foothills of the Cascade Range to the east, the principal geographic features have a general north-south trend.

4. Although the entire area drains ultimately to Puget Sound, it is divided naturally into four major drainage basins, namely, Lake Washington, Green-Duwamish River, Lake Union-Ship Canal and Puget Sound. Of these, the Lake Washington drainage basin is by far the largest, comprising about 350 square miles or nearly 60 per cent of the entire metropolitan area. Only 10 per cent of the area drains directly to Puget Sound.

5. Lake Washington, the largest of numerous fresh water lakes, is about 25 miles in length and has an average depth of 150 feet and a maximum depth of 220 feet. Puget Sound, which comprises the westerly boundary of the metropolitan area, is one of the deepest salt water basins in the United States and has an average depth of 600 feet.

6. Geologically, considerable horizontal and vertical variations can be expected in subsurface condi-

tions. Upland valleys and hills generally have a shallow weathered soil underlain extensively by hard cemented till. Upland soils generally provide good foundation conditions. Lowland valleys consist of alluvial deposits of soft clay, silts, and fine to coarse sands intermixed with gravel. High ground water tables, reaching the surface during the winter, are encountered in the lowlands. Piling and special bedding will be required frequently in the valley areas.

7. Marine air from the Pacific Ocean and the large water area of Puget Sound account for an equable year-round climate. Average daytime temperatures during the winter range from 40° to 50° F, while those at night are in the 30° to 40° range. Summer temperatures range generally from 70° to 80° F in the afternoon and from 50° to 60° during the night. Average maximum monthly temperatures range from 75.1° F in July, the warmest month, to 45.2° F in January, the coldest month. During 64 years of record at the Seattle weather station, the highest temperature was 100° F and the lowest was 3° F.

8. Rainfall occurs during a pronounced though not sharply defined rainy season and totals between 30 and 40 inches per year. In downtown Seattle, a total of 5.81 inches, or 18 per cent of the annual normal precipitation usually occurs during the five-month period, May through September. From 1951 through 1955, summer rainfall of 0.01 inch or more occurred during 173 hours, or only 4.6 per cent of the total hours in the season.

Chapter 4. Economic Development

1. Land uses in the metropolitan area range from intense residential, commercial and industrial in the city of Seattle to undeveloped cut-over lands and second growth timber around the periphery of the area. At present, over 50 per cent of the residential development is taking place outside Seattle.

2. Industry has been a dominant force in economic development. Centered initially on extractive industries such as forestry, fishing, and mining, operations have expanded and now include a variety of new products, among which are transportation equipment, building materials, textiles, and sporting goods. Aircraft manufacturing, by far the largest industry, accounts for three out of every five workers presently employed. Water, air and rail transportation, trade and commerce, fisheries, and military installations comprise other important segments of the metropolitan economy. Industrial expansion is expected to continue by the addition of such new industries as oil refining and the manufacture of petrochemical and synthetic chemical products.

3. Water supply and power facilities constitute two of the most valuable economic resources of the area. Natural gas is now available and provides a further inducement to industrial development.

4. Outstanding opportunities for recreation, especially boating and fishing, coupled with the area's scenic beauty, serve to attract tourists and to stimulate immigration.

5. Potential industrial employment is estimated to be 200,000 at ultimate development. At a gross density of 8.0 persons per acre, this means that a total of about 25,000 acres will required for industry.

Chapter 5. Population

1. For sewerage and drainage planning purposes, forecasts of population growth and distribution to the year 2030 were made with the assistance of the planning commission staffs of King and Snohomish counties and of the city of Seattle. These are shown below. For financial planning purposes, somewhat lower figures, representing the least growth likely to occur, were used.

	Population in thousands			
	1957	1980	2000	2030
State of Washington	2,670	4,320	6,500	10,600
Central Puget Sound Region[a]	1,370	2,240	3,380	5,500
King County	859	1,290	1,690	2,400
Snohomish County	134	264	592	1,100
Survey study area	864	1,260	1,740	2,240

[a]*Comprising King, Snohomish, Kitsap and Pierce counties.*

2. Population densities within the city of Seattle now range from 6.9 to 30.0 per acre, while those outside the city range from 0.5 to 4.7 per acre. Within the city, densities 70 years hence are estimated to range from 8.3 to 23.1 per acre, with an average of 12.3 per acre. Outside the city, the estimates range from 2.4 to 10.5 per acre and average 6.0 per acre.

PART III. EXISTING SEWERAGE, SEWAGE DISPOSAL AND DRAINAGE

Competent planning and design of sewerage and drainage facilities require a thorough knowledge of existing facilities, of the characteristics of the sewage to be dealt with, and of the environmental and economic effects of present deficiencies. Part III presents a description of the facilities now in use, a discussion and interpretation of sewage analyses, and a summary of conditions and problems which are in need of correction.

Chapter 6. Existing Sewerage and Drainage Facilities

1. Responsibility for providing sewerage service within the study area is presently divided among 41 separate agencies, including 19 cities and 22 sewerage districts. Of these, only 15 now operate sewerage systems. In addition, however, there are eight

semi-public and private systems which serve limited areas.

2. Existing sewerage facilities consist of about 1,550 miles of sewers, 75 sewage pumping stations and 25 sewage treatment works. About 1,040 miles of combined sewers are presently in use, essentially all of which are in the city of Seattle.

3. Existing treatment plants have an aggregate capacity of about 28 mgd, or only enough to treat about one-third of the present average daily dry weather output. The remaining output, amounting to about 50 mgd, is discharged without treatment through about 60 outfalls scattered along Puget Sound, Elliott Bay, Duwamish River, Lake Union and the Lake Washington Ship Canal system.

4. Only 70 per cent of the metropolitan population is now served by public sewers. The remainder must provide and maintain private septic tank systems. Private systems are being constructed at an average rate of about 6,000 per year.

5. Essentially all sewers outside the city of Seattle are of the separate sanitary type. Within the city, there are 1,029 miles of combined sewers and 204 miles of separate sanitary sewers. Outside Seattle, only four cities and one sewer district have storm drainage facilities worthy of note.

6. The Seattle sewerage system is composed of four major and numerous small independent systems. About one-fifth of the dry weather flow is treated at the five plants operated by the city, while the remainder is discharged without treatment. In addition to numerous raw sewage outfalls, there are about 60 bypass stations where combined sewage is discharged to adjacent waters nearly every time it rains.

7. Design capacities of most of the combined sewers are sufficient to carry no more than the flow resulting from a two-year storm. For that reason, and also because many of the systems have been overextended, overloads are frequent and cause sewage to back up into basements and to overflow from manholes.

8. While relief sewers have been provided from time to time, remedial measures have consisted mostly of interconnections between systems which were originally intended to function independently.

Chapter 7. Sewage Characteristics

1. Field and office studies were undertaken to develop design factors for (1) sewage volume, sewage strength and composition, (2) ground water infiltration, and (3) direct storm water entrance to sanitary sewers.

2. Continuous flow measurement devices were installed at 7 locations and additional flow data were obtained from records of 11 treatment plants. Minimum flow gagings were made at 50 points in the Lake City and Southwest Suburban systems to determine rates of infiltration. Composite samples for laboratory analysis were collected at 2 metering stations and 5 treatment plants.

3. A sanitary sewage contribution of 60 gpcd was decided upon for design purposes and represents a moderate increase compared with the present contribution. For design of trunk sewers within a major tributary area, the selected peak flow rate is 175 per cent of average. For trunks serving more than one major sewerage area and for treatment works, a peak of 150 per cent of the average is considered adequate. For presently developed industrial areas, an average waste contribution of 4,000 gpad and a peak of 8,000 gpad are in line with present experience. For new light industrial zones occupying an area of 1,000 acres or more, the allowance is 2,000 gpad. For heavy industrial zones smaller than 1,000 acres, a value of 4,000 gpad is appropriate.

4. Infiltration allowances applicable to existing sewers are 1,200 gpad for the wet season and 300 gpad for the dry season. For new sewers, similar allowances are 600 gpad and 300 gpad respectively. Storm inflow allowances are 2,000 gpad for existing sewers and 500 gpad for new sewers.

5. Values of 0.20 ppcd for BOD and 0.25 ppcd for suspended solids were determined to be applicable for sewage treatment plants in the metropolitan area.

6. Rates of infiltration and storm inflow in the Lake City system vary over a wide range and are excessive in certain local areas. Excessive infiltration and storm inflow rates were found also in many of the existing systems.

Chapter 8. Environmental and Economic Effects of Sewerage and Drainage Deficiencies

1. Environmental effects stemming from sewerage and drainage deficiencies in the metropolitan Seattle area range from minor nuisances to conditions involving a significant hazard to community health and well being. Economic effects include damage to property and impairment of water uses.

2. On the basis of design criteria employed until recently, overloading of combined sewers in Seattle can be expected to occur on an average of at least once every two years. Over 50 per cent of these sewers are overloaded and many of them have been extended to serve areas far in excess of those originally intended.

3. During the past six years, 692 complaints were received by the engineering department in regard to the backup of sewage into basements. Sewage flooding of streets and washouts in the vicinity of overflowing manholes are frequent occurrences.

4. While essentially all of the sewerage systems outside Seattle are composed of separate sanitary

sewers, high rates of infiltration and storm inflow occur in many cases and overtax both sewer and treatment plant capacities.

5. Approximately 100 square miles of the metropolitan area, with a population of 260,000 persons, is presently in need of public sewerage service. Close to 85,000 individual household disposal systems are now in use.

6. Septic tank installations depend on leaching systems for effluent disposal. Due to poor drainage conditions generally prevailing in the metropolitan area, these installations are failing at a rate of about 6,000 per year.

7. Septic tank overflows are common occurrences in unsewered areas which are heavily developed. In some sections, conditions have become so intolerable that subdividing and building have been greatly curtailed.

8. Construction, maintenance and repair of private sewage disposal systems are estimated to cost in excess of $3.2 million per year. An annual outlay of that magnitude would finance nearly $50 million worth of public sewers and would be sufficient to provide public sewers for essentially all of the area presently in need of such facilities.

9. Lack of trunk sewerage facilities for conveying sewage from inland areas to suitable points of treatment and disposal is one of the principal deterrents to local sewerage construction. Failure to provide these facilities is resulting in (1) exhaustion of financial resources in construction of temporary treatment works, (2) curtailment of desireable land developments, and (3) continued degradation of Lake Washington by discharges of both raw and treated sewage.

10. Numerous studies have shown that water resources of the area are being seriously impaired as a result of indescriminate waste discharge practices. Together with present findings, these studies show (1) that most of the public recreational waters fail to meet acceptable bacteriological standards, (2) that visible and odor nuisances prevail in the vicinity of points of raw sewage discharge, and (3) that waste discharges are exerting degrading chemical and biological effects on the waters of Duwamish River and Lake Washington.

11. Storm drainage facilities are generally lacking in the suburban areas. As a consequence, localized flooding occurs during periods of moderate to heavy rainfall.

PART IV. BASIS FOR PLAN DEVELOPMENT

Before proceeding with the development of sewerage and drainage plans, it is necessary to establish specific bases for design. This in turn involves a determination, evaluation and analysis of a series of factors, among which are (1) legal requirements governing the discharge of sewage and industrial wastes, (2) beneficial water uses to be protected, (3) characteristics of potential receiving waters, and (4) potential waste disposal sites. It also involves development of design criteria and of bases for estimating costs, and division of the study area into units for detailed planning.

Chapter 9. Principles and Functions of Sewerage and Drainage.

1. For nearly thirty centuries sewerage has been allied with the growth of urban centers. The average citizen, nevertheless, has little knowledge regarding the basic concepts and processes involved.

2. All sewage, regardless of its origin, is a potential hazard to public health and to community comfort and well being. As such, it must be removed promptly from all premises and must be disposed of in a manner which is safe and innocuous both from a public health standpoint and from a water pollution standpoint.

3. Requirements relating to sewage disposal, as established under state and other legislation, are administered in the state of Washington by the Pollution Control Commission.

4. Collection systems for sewage and storm water may be of either the combined or separate type. In combined systems, both sewage and storm water are conveyed in a single conduit. In separate systems, they are conveyed in separate conduits.

5. Construction of combined sewers has declined in the United States during the last 75 years. This is due largely to the high cost both of providing treatment capacity for combined sewage and storm flows and of constructing interceptors capable of carrying such flows without indescriminate bypassing.

6. Sewage treatment comprises the removal of relatively small amounts of mineral and organic material from the transporting water. Relative proportions thus removed define the degree of treatment.

7. Disposal conditions, particularly those relating to the ability of a receiving water to dilute and disperse sewage effluent, determine the degree of treatment required prior to disposal at a given site.

8. Primary treatment generally includes screening, grit separation, sedimentation, and separate digestion and disposal of the putrescible matter removed by sedimentation.

9. Secondary treatment utilizes biologic oxidation processes to remove dissolved and colloidal substances not affected by primary sedimentation.

10. Disinfection, meaning the destruction of disease-producing organisms contained in sewage, may be accomplished prior to disposal of either primary or secondary effluent.

11. Experience elsewhere demonstrates the economic desirability of establishing a metropolitan agency for the provision of sewerage service to a metropolitan area.

12. Of the many different types of sewerage agencies which can be formed in Washington, only one, a metropolitan municipal corporation, is legally capable of undertaking area-wide projects of the magnitude and scope required in the metropolitan Seattle area.

Chapter 10. Sewage Disposal in Lake Washington

1. Inland lakes and streams of the metropolitan Seattle area must be preserved and their waters must be protected from contamination and pollution by sewage discharges.

2. At present, approximately 20 per cent of the population of the metropolitan area resides in the immediate vicinity of Lake Washington. Over 50 per cent of the ultimate population is expected to reside within its drainage basin.

3. Lake Washington is the natural drainage basin for an area of approximately 182 square miles. In addition, it receives runoff from 402 square miles of adjacent basins. Outflow from the lake is discharged to Shilshole Bay through a series of ship canals, Lake Union and the Government Locks.

4. Water uses of Lake Washington and its tributaries are mainly recreational, including swimming, boating and fishing. Other uses are for private and public water supply purposes, and for fish propogation. Waters of Lake Union and the ship canal are used primarily for shipping and navigation.

5. Physical and bacteriological impairment can be prevented by adequate sewage treatment and disposal. Chemical impairment through mineral enrichment cannot be prevented by any economical treatment process. The capacity of waters in the Lake Washington drainage basin to receive sewage, therefore, is based on the ability of the lake to tolerate inflows of fertilizing substances, principally nitrogen and phosphorus.

6. Major tributary streams and sewage discharges are the principal sources of nitrogen and phosphorus entering Lake Washington. More than 98 per cent of the natural surface runoff into the lake occurs from nine principal tributary streams. These streams also contribute the major portion of nutrient inflow from natural sources. Treated sewage from a contributory population of 64,000, coupled with septic tank seepage from an unsewered population of 13,500 constitutes the principal source of nutrient inflow from sewage. In addition, sewage reaches the lake from combined sewer overflows in the city of Seattle. Untreated industrial wastes are discharged by the Boeing aircraft plant at Renton.

7. During winter months when runoff in the tributary streams is at a maximum, natural sources account for the major portion of nutrient materials. During summer months sewage sources gain in relative importance.

8. The estimated amount of nitrogen entering Lake Washington each year from sewage sources has more than doubled in the past 40 years. In the same period, the amount of phosphorus has increased by almost 300 per cent.

9. Expressed in terms of total input, sewage contributions of nitrogen are expected to increase from 6.5 per cent at present to an ultimate maximum of 35.2 per cent. Similarly, sewage contributions of phosphorus are expected to increase from 43 per cent at present to 92 per cent.

10. The biological response of a lake to fertilization may be manifested in several ways. Increasing fertilization is accompanied by an increased population of microscopic plant and animal life (plankton). Waters low in nutrient materials usually contain plankton of the diatom species, whereas those high in such materials usually contain large numbers of blue-green algae. Growths of the latter are frequently manifested by turbid water and disagreeable odors.

11. Plankton counts in Lake Washington almost doubled during a 5-year period, 1950 to 1955. In 1933, the organisms were predominantly diatoms. In 1957, the predominant forms were blue-green algae.

12. Studies of lakes in southeastern Wisconsin by C. N. Sawyer showed that nitrogen and phosphorus were the critical elements in relation to plankton productivity. From data then obtained, it was concluded that nuisance conditions resulting from excessive biological activity could be expected when the concentration of inorganic phosphorus in the water equals or exceeds 0.01 ppm.

13. Based on nutrient contributions and physical conditions in Lake Washington it appears that the inorganic phosphorus concentration that can be tolerated approaches 0.02 ppm as a limit. This concentration would require a total input of phosphorus of between 10 and 17 pounds per acre per year.

14. Since the diversion of Cedar River to Lake Washington in 1916, the quantity of phosphorus supplied to the lake from natural sources amounts to 9 pounds per acre per year, or about the lower limit of the tolerance range. Phosphorus supplied from sewage sources has increased steadily from about 2 pounds per acre per year in the 1916-1930 period to a present input of 6 pounds per acre per year. In other words, the total input from natural and sewage sources now approaches the upper limit of the tolerance range. Failure to reduce the amount of phosphorous entering the lake will lead to its eventual destruction as a recreational and esthetic asset.

15. The only practical method by which the phosphorus supply to Lake Washington can be reduced is through the elimination of all discharged thereto both of raw sewage and of sewage treatment plant effluents.

16. Bacteriological contamination of the waters of Lake Washington by storm water overflows from the combined sewer system of the city of Seattle can be brought under practical control by reducing the frequency of overflows to an average of once per recreational season. Contamination by miscellaneous raw sewage discharges, principally from house boats and yachts, should be controlled by the local agency in the affected area.

Chapter 11. Sewage Disposal in Puget Sound

1. Disposal of sewage in tidal waters must not impair present beneficial uses of the waters of Puget Sound or endanger anticipated future uses. Beneficial uses adjacent to the metropolitan area include recreation, fishing and fisheries, navigation, and industrial and commercial operations.

2. As related to possible points of sewage disposal, water quality criteria established by the Pollution Control Commission indicate that the bacterial concentration resulting from a sewage discharge is the controlling factor. If applicable bacteriological criteria are met, conditions with respect to other criteria also will be satisfactory.

3. Characteristics of Puget Sound which affect sewage disposal include those of temperature, dissolved oxygen, density, and current movement. Because of the relatively large tidal variations in the sound, mainstream currents are due predominantly to tidal rather than wind action.

4. Results of studies made elsewhere were utilized in developing graphic methods for estimating initial dilution and subsequent dilution and disappearance of coliform organisms.

5. Results of studies made elsewhere, together with results of a biological survey in the vicinity of the raw sewage discharge from the North Trunk sewer, indicate that submarine disposal of digested sludge would be feasible.

6. Disposal of digested sludge through an independent outfall should be undertaken on a trial basis at the new Alki Point treatment plant. Controlled disposal at that point, coupled with a comprehensive monitoring program for a period of about five years, would provide conclusive information needed for the design of future installations.

7. Studies were made in Puget Sound to determine the action of local eddy currents and longshore currents which prevail at possible disposal sites. Data from previous studies, and from investigations made with the hydraulic model of the sound at the University of Washington, were utilized in planning the current studies and evaluating their results.

8. Currents were measured at depths up to 400 feet, using a number of free-floating biplane drags suspended at fixed depths from small surface floats. Positions of the floats were determined at approximately hourly intervals.

9. Each of the possible disposal sites was analyzed to determine both the degree of treatment required and the length and depth of the submarine outfall. In these analyses, the controlling criterion was that of keeping the maximum concentration of coliform organisms at critical shore locations below the limit established by the Pollution Control Commission.

Chapter 12. Sewage Disposal in Green-Duwamish River

1. In its downstream reaches, Green-Duwamish River flows through areas in which future industrial and residential developments can be expected. Use of its waters for waste receiving purposes is of paramount importance to the future of the metropolitan Seattle area.

2. Green River originates in the Cascade Mountains east of Auburn. Duwamish River is formed by the confluence of the Green and Black rivers in the Renton-Tukwila area and discharges to Elliott Bay. Tidal effects presently extend about 90,000 feet upstream from the mouth of the river. Following construction of the proposed waterway extension, these effects will not extend beyond Orillia, a distance of about 58,000 feet upstream. Minimum flow in Green River during a 10-year period from 1944 through 1953 was 110 cfs. This minimum will be increased to 180 cfs on completion of the proposed Eagle Gorge Dam.

3. Beneficial water uses in the Green-Duwamish river system are diversified and include fish propagation and migration, shipping and navigation, and irrigation. Other uses are for industrial and waste disposal purposes, and for recreational fishing and boating.

4. Sewage and industrial waste disposal practices which satisfy the requirements for fish propagation and migration and for irrigation of crops will be sufficient to satisfy all other requirements with respect to beneficial uses. For the protection of fish life, the required condition is a dissolved oxygen concentration of not less than 5.0 ppm. For crop irrigation, the requirement prescribes a median coliform count not to exceed 50 per 100 ml, providing the contaminating organisms are of human origin.

5. Dissolved oxygen concentrations in Green-Duwamish River are presently approaching the minimum prescribed by the Pollution Control Commission, indicating that the river has about reached its limit for the safe disposal of sewage.

6. Based on conditions of minimum river flow and maximum water temperature, 20,000 pounds of 5-day BOD per day can be discharged at Auburn without reducing the dissolved oxygen concentration of Green River below 5.0 ppm. Of this load, 18,000 pounds will still remain in the river as it enters the Duwamish estuary. Downstream significance of this residual is dependent on the self-purification capacity of the estuary.

7. In terms of 5-day BOD, the maximum load which can be discharged to the head end of the existing Duwamish estuary is slightly in excess of 5,000 pounds per day. This can be increased to 10,000 pounds per day by moving the point of discharge downstream to Black River junction. In the proposed Duwamish estuary, the maximum 5-day BOD loads which can be discharged at Orillia and at Black River junction amount to 10,000 and 15,000 pounds per day respectively.

8. Maximum BOD loads which can be safely discharged to Green River at Auburn without reducing the dissolved oxygen concentration in the estuarial portion of the river system below 5.0 ppm amount to 7,000 pounds per day in the existing Duwamish estuary system and to 12,000 pounds per day in the proposed estuary system.

Chapter 13. Design Criteria and Basis of Cost Estimates

1. All projects discussed herein are laid out to serve ultimate development of the tributary area. As here used, "ultimate" refers to conditions expected about 70 years in the future, or about the year 2030.

2. Design criteria pertaining to trunk sewers, storm drains, intercepting sewers, pumping stations and treatment plants are based on the assumption that all new areas will be served by separate sanitary sewerage systems.

3. Unit design quantities for sanitary sewerage systems are based on studies of local sewage characteristics and take into account expected future variations. They also anticipate establishment of appropriate regulations by responsible agencies to set limits on physical and chemical characteristics which would produce undue loadings or detrimental effects on processes or structures

4. Design of storm drainage systems is based on use of the rational method, represented by the formula $Q = ciA$, wherein Q is the runoff rate in cubic feet per second, c is a selected coefficient of runoff, i is the mean intensity of rainfall of a specific duration and frequency in inches per hour, and A is the tributary area in acres.

5. Design of interceptor systems in areas served by combined sewers must make provision for certain quantities of storm water to minimize overflows to recreational waters.

6. Detailed analyses of rainfall records, overflow frequencies and interceptor capacities indicate that use of storm water holding tanks represents the most feasible method of providing capacity for storm flows originating in combined systems. Installation of such tanks at appropriate locations will reduce overflow frequencies to a safe level.

7. All construction costs used herein are based on an Engineering News-Record construction cost index of 800. This value represents bidding conditions in the spring of 1958.

8. Unit costs for construction of gravity sewers and storm drains, as well as those for force mains, inverted siphons and outfalls, are based on actual construction costs in the Puget Sound area.

9. Construction costs for pumping stations and treatment plants were developed from known costs of comparable facilities elsewhere and are based on the provision initially of basic structural units having a capacity sufficient to meet ultimate needs.

10. Annual costs include charges for interest, depreciation, and operation and maintenance. Interest was assumed to average 5 per cent per annum. Depreciation was computed by the sinking fund method, with interest at 5 per cent. Computations were based on a 50-year life for sewers and other conduits, including outfalls, and on a 30-year life for pumping stations and treatment plants. Annual charges for operation and maintenance were developed from records of various agencies operating facilities similar to those considered for the metropolitan Seattle area.

Chapter 14. Sewerage and Drainage Areas

1. One of the basic requirements in planning comprehensive sewerage and drainage facilities for a large area, such as metropolitan Seattle, is the division of that area into more or less independent units. Units for drainage planning are limited almost exclusively by topography, while those for sewerage planning are limited and defined not only by topography but by economic and political considerations as well.

2. Except for the southeast border, the metropolitan Seattle sewerage study area is defined by watershed boundaries. An arbitrary boundary was established along the southeast border because watersheds of the Cedar and Green rivers and of Issaquah Creek extend beyond any probable urban development.

3. The study area consists of four primary watersheds. For purposes of sewerage planning, these were divided into 12 major sewerage areas, which in turn were further subdivided into a number of smaller units designated as local service areas.

4. Due to inherent differences in the principles of design, drainage areas usually differ from sewerage areas. Drainage planning is usually confined to small, integral units having a suitable outlet to the

nearest available point of disposal. In any event, drainage planning for local areas within each unit must allow properly for storm flows tributary to it from upstream sources.

PART V. SEWERAGE AND DRAINAGE PLANS S

As a final step in the development of long-range sewerage and drainage projects, it is necessary not only to determine what alternatives are reasonably available but to evaluate and compare such alternatives on the basis of cost and other pertinent factors. It is necessary also to formulate programs of stage or incremental construction for all the recommended facilities.

Chapter 15. Development of Sewerage Plans

1. Problems of metropolitan sewerage are generally solved with greatest satisfaction and economy when the sewage of the entire area is concentrated either at a single point or at a relatively few points for treatment and disposal.

2. Due to the requirement that all sewage and treatment plant effluents be removed from the Lake Washington watershed, final disposal of the metropolitan area sewage is limited to Puget Sound and the Green-Duwamish River.

3. Four sites were selected for possible construction of sewage treatment plants. These are designated as West Point, Government Locks, Elliott Bay, and Renton. Of the four, West Point is the most satisfactory in terms of meeting basic requirements for a treatment plant location.

4. Four central sewerage projects, designated herein as core plans, were developed for a detailed analysis and for comparison on the basis of construction cost and total annual cost. These projects were as follows:

Core Plan A. Conveyance of all sewage from the area to a single primary type treatment plant at the Government Locks site with effluent disposal to Puget Sound off West Point.

Core Plan B. Conveyance of sewage from the area to two treatment plants, one a primary type at the West Point site with effluent disposal to Puget Sound, and the second a complete type at the Renton site with effluent disposal to Duwamish River.

Core Plan C. Conveyance of sewage from the area to two treatment plants, both primary type. Of these, one would be at the West Point site with effluent disposal to Puget Sound, and the second at the Elliott Bay site with effluent disposal to Elliott Bay.

Core Plan D. Conveyance of sewage from the area to three treatment plants. One would be a primary type at the West Point site with effluent disposal to Puget Sound, the second a primary type at the Elliott Bay site with effluent disposal to Elliott Bay, and the third a complete type at the Renton site with effluent disposal to Duwamish River.

5. Estimated construction costs for the four core plans range from a total of $51,029,000 for Plan D to $73,932,000 for Plan A. For Plan B, which is the second lowest, the estimated construction cost is $54,346,000, or 6.5 per cent higher than Plan D.

6. Total annual costs for the four core plans range from $4,203,000 for Plan D to $5,708,000 per year for Plan A. For Plan B, the annual cost is $4,233,000, or less than one per cent higher than Plan A.

7. Because of the small difference in annual cost between Core Plan B and Core Plan D, other factors had to be considered in determining which would be the more acceptable. These factors include such items as duplication of operation; interference with business activity during construction; possible future upgrading of disposal requirements; ability to expand facilities in the event that the estimated growth of the tributary area is exceeded; simplicity and flexibility of the treatment process; and esthetic impression.

8. Based on a consideration both of the foregoing factors and of first cost and total annual cost, it is concluded that the most satisfactory plan for central sewerage of the metropolitan area is represented by Core Plan B.

9. Three possible modifications of Core Plan B were investigated. These involve (1) conveyance of sewage, including that from the North Lake Sammamish, South Lake Sammamish and East Lake Washington sewerage areas, from the east to the west side of Lake Washington across the lake rather than south to the Renton treatment plant; (2) construction of a primary type treatment plant at the Renton site, with effluent disposal to Puget Sound rather than a complete type treatment plant with effluent disposal to the Duwamish River; and (3) construction of a complete type treatment plant at the Government Locks site with effluent disposal to the Lake Washington Ship Canal in lieu of a primary type plant at the West Point site. For all of these, the estimated construction costs and total annual costs are substantially higher than those for the proposed project under Core Plan B.

10. Due to problems involved in crossing Lake Washington from an independent treatment plant on the east side of the lake, no economical alternative to the central sewerage project is available to the East Lake Washington and South Lake Sammamish sewerage areas.

11. Five plans for independent sewerage of the North Lake Sammamish, North Lake Washington and Northwest Lake Washington sewerage areas were laid out and their costs were estimated. From the information thus developed, it is evident that the most eco-

nomical means of sewage collection, treatment and disposal for the three areas is through the central sewerage project.

12. Two plans for independent sewerage of the South Lake Washington and Green River sewerage areas were investigated. Although the estimated costs favor a plan calling for construction of a treatment plant north of Auburn in addition to the plant at the Renton site, receiving water and other conditions are such that these two areas can best be served under Core Plan B.

13. No reasonable alternatives to the central sewerage project are available to the Southwest Lake Washington, Elliott Bay and Lake Union sewerage areas.

14. In the South Puget Sound sewerage area, the most economical plan is one under which facilities for sewage collection, treatment and disposal would be provided independently in each of five individual subareas. New primary type treatment plants would be constructed in two of the subareas, Redondo Beach and Miller Creek, and a new complete type plant would be constructed in the Des Moines subarea. Existing primary type treatment plants in the Southwestern Suburban and West Seattle subareas would be fully utilized and secondary treatment facilities would be added at the Southwest Suburban plant. All plants would discharge effluent to Puget Sound.

15. In the North Puget Sound sewerage area, which comprises one small subarea, Seaview, and two principal subareas, Piper Creek and Boeing Creek, the most economical sewerage plan again is that of constructing independent facilities in each individual subarea. Under this program, primary type treatment plants are to be constructed in the Piper Creek and Boeing Creek subareas, with both discharging effluent to Puget Sound.

16. Because of the magnitude of the work which will have to be undertaken in developing the sewerage system recommended for the metropolitan Seattle area, it is unlikely that any single existing political agency could finance construction of the required facilities. It is not likely either that existing agencies acting individually could attain the desired objectives. It seems apparent, therefore, that such a project will require the formation of a central agency encompassing the entire metropolitan area. This agency would be responsible for all administrative and engineering duties relating to the financing, design, construction, maintenance and operation of the recommended sewerage facilities. In addition, it should take over and become responsible for operation and maintenance of all existing sewage treatment plants in the metropolitan area.

Chapter 16. Stage Construction of Sewerage Facilities

1. Development of a long-range program of sewerage improvements requires, as a final step, the scheduling of construction work in accordance with present need and expected growth. Additionally, consideration must be given to the effective utilization of available engineering and construction forces and to problems involved in financing the various projects.

2. Stage I construction, scheduled to start in 1960 and to be completed by 1970, provides for relief of the most urgent sewerage needs of the metropolitan area. In addition to treatment plants at two sites, West Point and Renton, this stage includes facilities to (1) intercept major sewage discharges to Lake Washington, (2) intercept raw sewage and industrial waste discharges to Duwamish River, Elliott Bay, and Puget Sound, and (3) provide service to highly developed areas presently without public sewerage. Estimated construction cost of facilities to be provided under Stage I amounts to a total of $83,215,000.

3. Upon completion of facilities for the Renton system under Stage I, central sewerage service will be available to the East Lake Washington, South Lake Washington, and Green River sewerage areas. Intercepting and trunk sewers will be constructed in these areas to effectuate the program of removal of sewage and sewage effluent discharges to Lake Washington. The Renton sewage treatment plant will be of the complete type employing the activated sludge process and will have a capacity of 24 mgd, average dry weather flow. This capacity will be sufficient for 15 to 20 years.

4. Stage I construction in the West Point system includes intercepting and trunk sewers to (1) intercept a major sewage discharge to Lake Washington at Lake City, (2) intercept raw sewage and industrial waste outfalls to Duwamish River and Elliott Bay, and (3) to provide service to developed areas presently without public sewerage. This stage also includes construction of a primary type treatment plant at West Point and a submarine outfall to Puget Sound. The West Point plant will have an initial capacity of 118 mgd, average dry weather flow.

5. Upon completion of Stage I construction, the West Point system will provide central sewerage service to the Northwest Lake Washington, Southwest Lake Washington, Elliott Bay and Lake Union sewerage areas.

6. Independent systems to be constructed under Stage I include those required to intercept raw sewage discharges to Puget Sound and to provide service to areas presently without public sewerage. This program comprises:

a. Construction of trunk sewers, primary type treatment plant, and submarine outfall in the Des Moines subarea, South Puget Sound sewerage area.

b. Construction of trunk sewers, primary type treatment plant, and submarine outfall in the Miller Creek subarea, South Puget Sound sewerage area.

c. Incorporation of existing sewers, existing sewage treatment plant and submarine outfall of the Southwest Suburban Sewer District, and construction of trunk sewers in the Southwest Suburban subarea, South Puget Sound sewerage area.

d. Incorporation of existing sewers, sewage treatment plant and submarine outfall of the city of Seattle in the West Seattle subarea, South Puget Sound sewerage area.

e. Construction of trunk sewers, primary type treatment plant and submarine outfall, and incorporation of existing sewers of the city of Seattle in the Piper Creek subarea, North Puget Sound sewerage area.

f. Construction of trunk sewers, primary type treatment plant and submarine outfall in the Boeing Creek subarea, North Puget Sound sewerage area.

7. Stage II construction, scheduled for the period 1970 to 1980, calls for extension of central sewerage facilities to the North Lake Washington and Green River sewerage areas. During this stage, the Renton treatment plant will be enlarged to accommodate an average dry weather flow of 48 mgd. Also called for are enlargement to ultimate capacity of plants serving the Des Moines and Miller Creek subareas; provision of secondary treatment facilities at plants serving the Des Moines and Southwest Suburban subareas; extension of submarine outfalls in the Southwest Suburban and West Seattle subareas; and construction of new trunk sewers, primary type treatment plant, and submarine outfall to serve the Redondo Beach subarea. Based on present day prices, the total cost of Stage II construction is estimated at $35,417,000.

8. Construction of the balance of the recommended facilities is provided for under Stage III. This work will be undertaken after 1980 as the need develops, and is estimated to cost a total of $45,366,000. Completion of Stage III construction will result in a sewerage system capable of serving the metropolitan area for many years.

Chapter 17. Development of Storm Drainage Plans

1. The extent to which storm drainage facilities are provided in urban areas depends on climate and topographic conditions, on the value of property to be protected, and on the ability and willingness of the public to meet the necessary costs.

2. For economic and other pertinent reasons, natural watercourses in the metropolitan Seattle area should be utilized to the fullest possible extent as storm drainage channels. Similarly, lakes of the area should be utilized as storm water storage or holding basins.

3. Since natural watershed boundaries generally transcend political boundaries, cooperation between political entities is required to protect watercourses and public and private property from damage due to storm water runoff. In the metropolitan Seattle area, such cooperation could be obtained if the administration of all major storm drainage facilities became the responsibility of the central agency recommended for administration of major sewerage facilities.

4. To demonstrate the method of runoff computation and conduit size selection and to provide a basis for a preliminary cost estimate of drainage, preliminary designs were developed for four typical drainage areas. These are designated as Kirkland-Houghton, Mountlake Terrace, Des Moines and Kent.

5. Topographic and other conditions in the Kirkland-Houghton area are conducive to effective and low cost drainage. Two plans were considered for this area, the first providing for use of open channels to the maximum possible extent, and the second for enclosed conduits throughout the system. Depending on the extent to which open channels can be used, provision of major storm drainage facilities in areas such as Kirkland-Houghton is estimated to cost between $270 and $440 per acre.

6. In the Mountlake Terrace drainage area, conditions are such that a portion of the runoff from one drainage basin could be diverted to another. Two alternatives were considered for this area. The first calls for diversion of the runoff from one drainage basin to another, and the second for disposal of runoff in each basin separately. Estimated construction costs for the two alternatives are virtually the same and amount to about $260 per acre.

7. Drainage in the Des Moines and similar areas can be achieved most economically by using natural watercourses to the fullest possible extent. Due to long distances to the final points of disposal, the cost of providing storm drainage facilities in areas of this type is relatively high and amounts to about $550 per acre.

8. Because extensive sections of the Kent drainage area lie below flood stage of the Green River, construction of storm drainage facilities is a difficult and expensive undertaking. Two alternatives were investigated for this area, each involving a different route for the major drains. Based on these findings, the cost of major storm drainage facilities in areas of this type is estimated to vary between $730 and $800 per acre.

9. Although it is impossible at present to estimate accurately the cost of providing major storm drainage facilities throughout the entire metropolitan Seattle area, an approximation thereof, based on unit costs for the four typical areas, can be developed for planning purposes. To that end, the metropolitan area was divided into five general categories and cost estimates were prepared, based on the applicable unit cost and on the total acreage within each such cate-

gory. As thus determined, the estimated cost of major storm drains required at ultimate development of the metropolitan area amounts to a total of $145 million. This total is exclusive of any improvements in the portion of Seattle served by combined sewers.

10. Based on the present stage of development in the metropolitan area, it is estimated that about one-fourth to one-third of the storm drainage facilities required for ultimate development should be constructed within the next 10 years.

Chapter 18. Separation of Combined Sewers in the City of Seattle

1. Seattle is faced with a diversity of problems brought about by the use of combined sewers for the conveyance of sewage and storm water. Correction of these problems can be achieved only by separation to some degree of both trunk and local collection systems.

2. Two basic factors relate to the planning of separation programs. First, construction of holding tanks in areas draining to Lake Washington provides the most economical means of preventing bacterial contamination of the lake due to storm water overflows. Second, unlimited storm water overflows are allowable in commercial waterways such as Lake Washington Ship Canal, Elliott Bay, and Duwamish River. As a result, separation need be undertaken only to the extent necessary to relieve overloaded trunk and local sewers.

3. Studies made in 1951 by the Seattle engineering department showed that the existing system is generally inadequate in terms of its ability to carry combined flows of sanitary sewage flows and storm water runoff. Studies made of six areas during the present survey showed in all cases that these portions of the system do not have sufficient capacity in their entirety to carry the flow resulting from a storm with a recurrence interval of 10 years. All of them, however, have a capacity sufficient to accommodate the peak flow of sanitary sewage.

4. Two degrees of separation were investigated. The first, partial separation, provides for a new storm drainage system of sufficient capacity to collect storm water runoff from streets and yards. The second, complete separation, provides for a new storm drainage system of sufficient capacity to collect all storm water runoff, including that from roofs and foundation drains.

5. The six areas selected for separation studies occupy a total of 2,860 acres, or about 8 per cent of the total area served by combined sewers in the city of Seattle.

6. Detailed studies of the six areas show that the estimated cost for partial separation varies from $1,690 to $2,170 per acre and averages $1,860 per acre. For complete separation, the estimated cost varies from $3,180 per acre to $4,570 per acre and averages $3,890 per acre. In both cases, the deviation from the average is less than 20 per cent.

7. Based on the average cost and on a total area of 37,000 acres sewered on a combined basis, the total cost of partial separation within the city of Seattle approximates $69 million.

8. Although separation is required throughout the city, steps should be taken immediately to provide separation in areas draining to Lake Washington and in other areas experiencing major problems caused by sewage overflows from combined sewers. This immediate program is estimated to cost $18 million.

9. To avoid future expenditures for separation, all new sewer construction in the city of Seattle should be on a separate basis. Sanitary sewers should be designed for the peak sanitary sewage flow only and separate storm drains should be installed as required.

10. New drainage systems in areas requiring separation should be designed with a capacity sufficient to accommodate the runoff from a 10-year storm, including that from roofs but not from foundation drains. These systems could be constructed initially to intercept street drainage only and could be extended later to critical areas to intercept roof leaders as required.

Chapter 19. Financing of Recommended Facilities

1. Based on a lower estimate of population growth than utilized for design purposes, the assessed valuation of metropolitan Seattle is expected to rise from $990 million in 1960 to $1,210 million by 1980. In the same period, the number of sewer service connections is expected to increase from 210,000 to 324,000.

2. Existing sewerage facilities, which either would be incorporated in a metropolitan system or abandoned because of the provision of such a system, have an approximate value of $9.4 million. It is proposed that local agencies be reimbursed for these facilities through assumption of their outstanding indebtedness by a metropolitan sewerage agency.

3. Annual outlays both for capital expenditures and for operation and maintenance will depend upon the rate at which the proposed sewerage works are constructed. Under a program requiring 10 years each for construction of Stage I and Stage II facilities, capital outlay will range from $7 million to $12 million per year during Stage I, and from $3 million to $4 million per year during Stage II. Annual costs of administration, operation and maintenance, both of permanent and temporary facilities (new and existing), are estimated to range from $832,000 in 1960-61 to $1,645,000 in 1978-79.

4. Use of general obligation bonds for financing the sewerage program would interfere with the financing of storm drainage improvements. Revenue bond financing of sewerage is the only practicable alternative. Total annual revenue requirements, including debt service coverage and operational costs, will range, using the 10-year Stage I program, from \$6.4 million during the first year in 1960 to \$9.2 million by 1979. As an upper limit, the equivalent residential service charge necessary to support this program will amount to \$2.50 per month for the first 8 years, and to \$2.40 for the next 12 years.

5. Since the estimated costs include those of operation, maintenance and debt service for many facilities now supported by service charges of local agencies, the metropolitan service charge would not necessarily be an addition to present charges. Locally, total service charges will vary with local debt service for collection sewers and the need for their extension or replacement.

6. Trunk storm drains needed now or in the near future, including those within Seattle required in conjunction with the separation program can be financed by general obligation bonds of a metropolitan agency. Resulting property tax rates would range from 0.35 mills in the first year to 3.15 mills in the tenth year of a 10-year construction program.

7. Partial separation of combined sewers in Seattle, other than major drains, is the responsibility of that city. Funds which can be made available for this purpose include reimbursement for existing sewerage facilities plus revenue from the present sewer service charge. Amounts thus obtained would enable separation within the Lake Washington watershed in four to seven years without resorting to financing by general obligation bonds.

Chapter 21
RECOMMENDATIONS

For convenience in reference, it is desirable in this final chapter, to consolidate all recommendations pertaining to the design, construction, and financing of the proposed sewerage and drainage facilities. In brief, it is recommended:

1. That the sewerage projects proposed herein be adopted as a long-range plan for the metropolitan Seattle area. These projects consist of (1) a central system designated as Core Plan B, (2) tributary feeder sewers and service sewers for the core plan system, and (3) independent systems in each of seven service areas immediately contiguous to Puget Sound.

2. That a central agency be established for financing, constructing, operating and maintaining, and administering the proposed sewerage projects.

3. That construction of sewerage projects be undertaken in accordance with the schedule herein set forth.

4. That construction of the required sewerage facilities be financed by means of revenue bonds.

5. That monthly service charges be established on a basis which will assure both sound financing and an equitable distribution of costs among all users of the metropolitan facilities.

6. That existing sewerage agencies be reimbursed for those facilities which are to be abandoned or are to be integrated into and made a part of the metropolitan system. In general, reimbursement should be in accordance with the schedule herein set forth and should be made in such manner as may later be determined to be feasible and equitable.

7. That, pending establishment of a central agency, the city of Seattle proceed with construction of those elements of the proposed projects which lie wholly within its boundaries.

8. That, pending establishment of a central agency and the provision of service by that agency, sewerage planning in areas outside the city of Seattle be directed toward the eventual connection of all local sewerage systems to the metropolitan system.

9. That, pending provision for removal of all sewage from the Lake Washington drainage basin, land disposal or any other practicable means be utilized to prevent new or additional discharges of sewage effluent into the surface waters of that basin.

10. That the city of Seattle undertake a continuing program for separation of combined sewers and that the practice of constructing combined sewers be discontinued.

11. That specifications for sanitary sewers, including house connections, be revised to require the use of pipe and pipe jointing materials and methods which will assure adequate tightness, and that acceptance of construction be predicated on meeting the requirements of a standard leakage test.

12. That a policy of prohibiting the connection of roof, yard, foundation and similar drains to sanitary sewers be established and vigorously enforced.

13. That sanitary sewers subject to excessive infiltration or storm water inflow be further investigated to determine the sources thereof, and that such steps as are necessary be taken to reduce infiltration and inflow to permissible limits.

14. That the city of Seattle undertake, on a trial basis, the disposal to Puget Sound of washed digested sludge from the Alki Point treatment plant, and that a monitoring program be conducted in accordance with specifications to be prescribed by the Pollution Control Commission.

15. That a program of monitoring receiving water conditions within the zone of influence of waste discharges be established and continuously maintained.

16. That a continuing program of research be conducted relative to all phases of the nutrient enrichment problem in Lake Washington.

17. That trunk storm drains be designed in accordance with the principles herein set forth.

18. That the provision of trunk storm drains be made the responsibility of the central agency.

19. That trunk storm drains be financed by means of general obligation bonds supported by an ad valorem tax spread over the entire area ultimately to be benefited by such drains.

20. That a policy be adopted aimed at (1) obtaining permanent rights-of-way for trunk drainage purposes, and (2) preserving natural drainage channels which are presently or may in the future be required for trunk drain routes.

21. That, as a matter of policy, metropolitan sewerage facilities be defined as those necessary to serve a minimum area of approximately 1,000 acres and that trunk storm drains be defined as those necessary to serve a minimum area of 160 acres.

22. That uniform industrial waste ordinances, designated for the protection of sewerage facilities and the prevention of water pollution, be adopted by all agencies contributing waste to any metropolitan facility, and that enforcement of these ordinances be made a requirement for participation in the metropolitan project.