Pasadena, Calif.

June 9, 1922

Mr. Franklin Thomas
Professor of Civil Engineering
California Institute of Technology

Dear Sir:

I beg to submit the following report of a study and investigations made on the problem of the Los Angeles Sewage Disposal.

The report includes a discussion of the more important and common methods of sewage treatment as well as a study of the relative costs of the outfall method of disposal and the activated sludge treatment plant.

Respectfully submitted,

Edward G. Kemp.

INTRODUCTION.

During the past ten years, Los Angeles has increased in population enormously, as shown by the census figures. In January 1920, the city had a population of over 570,000, which is an increase of 81% over its population of 319,000 in 1910. It has been estimated that there are two thousand people coming into the city every twenty-four hours. It is fast becoming a gigantic problem for the different departments of the city in the caring for this increase. Providence is indeed to be thanked that the city had as an engineer, a man of such far-reaching vision as William Mulholland to provide such an adequate water supply as is carried by the aqueduct from Owen's River -- a water supply of four-hundred second-feet. But unfortunately, it seems that as one important problem is solved, a new somewhat related problem confronts us, and that is the problem of disposal of the sewage in a satisfactory manner free from obverse criticism.

Los Angeles, almost since the first day of its incorporation, has used, with marked economy, the most natural method of sewage disposal, that of discharging the sewage into the Pacific Ocean. It is considered as purely a scientific process of purification as any other, if it is intelligently practiced within the safe limits of the digestive capacity of the water. However, it seems that the process is very much overworked at Hyperion, where the outfall sewer discharges into the ocean. The sewage-laden waters are very offensive to residents and bathers near the outlet. Sewage litter is noticeable along the beach and in the adjacent waters for a mile or more in either direction, particularly to the south. At

Hyperion, the amount of sewage has increased so rapidly within the last ten years, that it is fast becoming more and more insufficiently mixed with sea water. When the weather is warm and humid, there is present, along the bench, offensive odors suggestive of sewage. It is essential, that when this process by which the sewage disposed by dilution becomes overworked, to treat the sewage in some way to assist the natural process, which had previously prevented any nuisance -- the primary objects of such treatment being to change the character of the sewage, so that the effluents from the treatment works, will neither cause offensive conditions, nor be a menace to the health of innocent inhabitants.

If suspended solids alone were objectionable, this could be removed almost entirely by screening, but at Hyperion, the floating matter is not the only menace. Bacterial analyses have been made of the surf water which show that if bathers should happen to swallow some of the water, there would be attendent risks. This fact indicates the necessity of materially improving the disposal arrangements. Where the disposal by dilution fails, because of a lack of a sufficient supply of oxygen, it is only necessary that a part of the sewage be treated, so that an adequate supply of oxygen will be available for the remaining untouched sewage.

Before determining the exact type of treatment to be adopted, it is necessary to ascertain to what extent the objectionable matter will have to be removed from the sewage. After the determination to which extent the natural process must be assisted, a conclusion must be drawn as to which method of disposal or combination of methods will be used. When adopting a method for the disposal of sewage, it is important that such a process, or combination of processes, be selected, as will meet the needs or requirements of the present and immediate future, but at the same time lend themselves to later development of more effective means of treatment when they shall be required.

Following the ~~depot~~ defeat of the Sewer Bond Issue of $12,250,000.00 in June 1921, for the provision of the North Outfall sewer, it is of prime importance to the welfare of the City of Los Angeles, that other plans be made for the disposal of the sewage surplus of the immediate future as well as the present. Bonds for the installation of treatment plants would undoubtedly pass at the next election, as many voters who opposed the bonds for the outfall sewer, expressed themselves, at that time, as being in favor of treatment plants.

Methods of Disposal other than Dilution.

1. Screening.
2. Sedimentiation.
3. Contact bed treatment.
4. Trickling filter treatment.
5. Intermittent filtration.

Screening.

Grit Chambers.

The grit chamber is a trough designed to remove the inorganic matter, without depositing any of the organic matter. Grit settles from flowing sewage, according to its size and specific gravity and according to the velocity of the stream. A uniform velocity must be maintained in order to obtain a uniform separation of grit from the other settling solids. This uniform velocity is difficult to maintain, on account of the constant variation in the quantity of sewage and the large capacity of the chambers in proportion to the flow through them, during the early years of their use. The velocity of flow must not be so low that it will result in the deposit of the organic material. The chamber must be long enough so that enough time will be given for the particle of grit to reach a depth below which it will be prevented from escaping from the basin. The grit chambers should collect particles which settle out at velocities not less than one foot per second, if the remaining heavy materials can be handled easily in other parts of the treatment plant. It is more satisfactory to handle material which would precipitate out at velocities less than one foot per second in the sludge from settling tanks than to attempt its removal by grit chambers.

Grit chambers should not be expected to remove more than 10-40 p. p. m. of the suspended matter.

Screening.

Screens remove material likely to obstruct or injure machinery, to render diluting waters offensive as to sight and odor, and to cause deposits of material in the bed of the diluting water. Course screens are used for this purpose, made up of parallel bars about one-half inch apart. Fine screening removes a much larger percentage of this material, and is more of a treatment process, whereas coarse screening merely insures the satisfactory operation of disposal or treatment plant. Fine screens are made of perforated metal or wire cloth, the holes seldom being more than one-fourth inch in size. They should be kept clean and the velocity through them, should be kept down in order that sewage would not flow through, which should be intercepted.

Course screens will remove from five to ten p.p.m. of coarse material and fine screens may be expected to remove from twenty to seventy p.p.m. when conditions are ~~formable~~ favorable for screening.

Suspended matter disintegrates during the time that it is in the sewage system, which disintegrated matter (a large part of it), will not be retained on the screens. Thus the size of the screens should be determined by the nature of the sewage at the place of the screens. Screening may be accomplished before the sewage has had time to dis-integrate very much, which would bring about quite a saving at the treatment plant.

Sedimentation.

Sedimentation tanks are used in cases where it is desirable to remove a large part of the suspended solids containing organic sub-stances after the heavier matter has been removed by grit chambers or screens. Without sedimentation tanks, offensive sludge deposits would be formed, if these suspended solids were present in the sew-age flowage into a body of water.

Disinfection.

Disinfection of all sewage is advisable if the sewage is disposed into a body of water near bathing beaches, and is much more effec-tive if applied to sewage after clarification by sedimentation, than if applied to raw or screened sewage. The velocity of flow in the sedimentation tank appears to leave very little effect upon the efficiency of sedimentation, but the period of detention is very important, governing the quantity required by the conditions. The period may be very short, in some cases one-half hour, but is un-likely to be more than four to six hours.

Septic Action

Bacterial action in septic tanks differ from that in sedimenta-tion tanks, owing to the longer detention period, the degree to which bacterial action is carried, and the type of bacteria cultivated.

Anaerobic decomposition of the sewage begins after the number of bacteria have reached a certain amount, and the dissolved oxygen and nitrates have been exhausted. The sludge accumulating in the bottom of the tank is attacked by organisms, and is partly disintegrated. Accompanying these changes, gas is produced in the sludge, eventually the sludge becoming so light that it will rise to the surface. The practice of "seeding" is to place a small quantity of sludge from an active septic tank into a tank of fresh sewage, which materially decreases the time required to develop a septic condition.

Septic Sludge

Reduction in volume of the organic matter in the sludge in septic tanks, amounts to an average of about 30%. The sludge removed from septic tanks is not more than 20 - 25% of the volume removed from sedimentation tanks.

Chemical Precipitation.

Chemical precipitation is a method of increasing the sedimentation of suspended and colloidal matter by the addition of chemicals, which form floc in the liquid, the floc drawing to itself the substantives it is desired to remove. Lime, aluminum sulphate, iron sulphate are used to react with the matter in suspension; clay and soil are sometimes added to weight down the precipitate; charcoal is added as a deodorizer. The ferrous sulphate combines with the calcium hydroxide to form the flocculent precipitate, ferrous hydroxide, which brings down the suspended matter as it precipitates.

If enough chemicals are employed intelligently, the effluent with in general be clear, nearly free from suspended matter and nearly colorless. Sometimes the amount of chemicals required to do this is so great that there is a serious expense.

This method has not been generally adapted, as the effluent is ordinarily putrescible even if satisfactory in appearance. It is best adapted to treatment of industrial wastes.

Imhoff Tank.

The Imhoff tank is simply, in construction, a two story sedimentation tank. The solid material is allowed to settle out from the sewage and is then decomposed by anaerobic bacteria. Treatment by the Imhoff tank keeps the sewage in a fresh condition by not allowing the oxygen and nitrates in the sewage to become affected by the decomposition of the sludge. Sewage, on coming from the sewer first flows through a sedimentation chamber in which a great part of the solid matter is removed. These solids drop down through a slot in the bottom of the settling chamber into what is known as the sludge chamber, the lower story of the Imhoff tank. The gases of decomposition are trapped so that they cannot rise up through the sewage, but must pass up the outside of the wall of the settling tank. The Imhoff tank performs the functions of sedimentation and septic tanks.

The sludge from the Imhoff tank is easily disposed of. On being removed from the tank, it is spread out upon drying beds, and is buoyed up by the entrapped gases, which allows the liquid below to escape through the beds. The gas gradually frees itself from the suldge after the water escaped, leaving it quite porous, which porosity is advantageous as it hastens the time of drying.

For the detention period when the sewage is fresh, good practice recommends about three hours with an average of perhaps two hours. Rates of flow in the sedimentation chamber range from seven to about eighty-five feet per hour.

Activated Sludge.

The idea of activated sludge process started from a series of experiments at Lawerence Experiment Station in 1912 which had to do with the aeration of sewage. Later experiments were conducted at Manchester England, which had to do with the aeration of sewage in the presence of sludge. This treatment of sewage by aeration in the presence of the sludge is now generally called after the English, "activated sludge."

The principle utilized in the activated sludge treatment is the removal of suspended matter coupled with the aerobic decomposition of some of the organic matter and in some cases the subsequent nitrification of the ammoniacal compounds. The process consists in adding sludge to the raw sewage in proportions of about one to five and enough oxygen to maintain aerobic conditions is provided by aerating the sewage for a certain interval of time. The treated sewage is then agitated until a sort of flocculent precipatate develops, the sewage led into settling tanks where this sediment is precipitated and the clarified liquid passes off as effluent. The sludge not required for treatment of the incoming sewage is disposed of by drying on sand beds, and using the dried sludge for filling in land, pumping into lagoons which on drying up becoming suitable for raising crops or conversion into fertilizer by drying and pressing.

In this process such a large proportion of the suspended material may be removed that ordinarily the effluent will be clear and contain only a small amount of suspended matter and comparatively few bacteria. It is interesting to note that in this process a partial treatment may be given. If the removal of suspended matter and bacteria is all that is wanted, the process can be stopped short of material oxidation of organic matter and nitrification or the process can be operated to obtain complete stability of the effluent and the oxidation necessary. It may be impossible to accomplish all this without the addition of chemicals if the sewage contains industrial wastes of disturbing character.

Contact Beds

The purpose of contact beds is to transform the organic matter in the tank effluents into material which would not demand so much oxygen that they would not exhaust the supply in the waters receiving the effluents and produce putrefactive conditions. The contact bed was a step forward in sewage treatment before the invention of the activated sludge process. The bed is operated by filling it with sewage, allowing it to stand for a time, then drawing off the sewage and allowing it to rest empty. The changes taking place in the sewage are physical, biological and chemical. The disadvantage of contact beds is that they are limited in capacity and the cost is too great as compared to the benefits derived from other processes.

Trickling Filters

The trickling filter is not limited in capacity as is the contact bed as the sewage flows continuously through them. The sewage is applied as uniformly as possible by sprinklers or other devises and is allowed to trickle slowly over the stones and has sufficient opportunity to give up colloidal and dissolved substances to the bacterial jelly. The bed may absorb oxygen continuously which lessens the danger of anaerobic conditions. The filter converts putrescible settled sewage into stable effluent not subject to putrefaction. A difficulty presents itself in that irregular distribution of the sewage over the surface has not been overcome by any means so far produced. Thus the effluent is composed of portions of the applied sewage which has received varying degrees of oxidation. Neither contact beds nor trickling filters alone will remove bacteria.

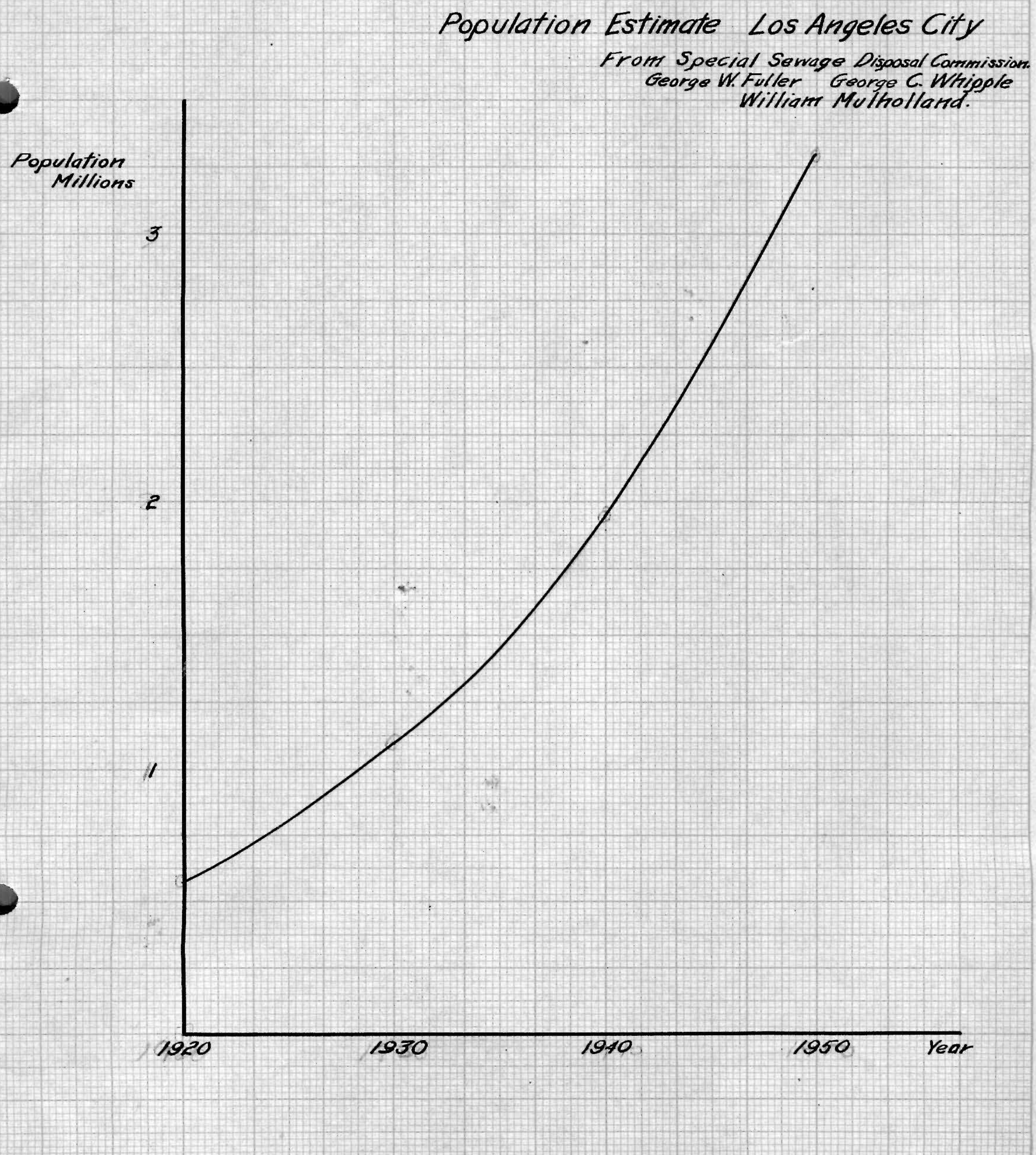
Intermittent Sand Filters.

Applying sewage intermittently and uniformly over a bed of well drained sand for a considerable period causes the removal of the suspended matter by the straining action of the sand and the oxidation of the suspended matter, dissolved as well as suspended, by the bacteria living in the bed.

Due to the straining action of the sand, suspended solids are left in the upper part of the filter where the organic matter is subject to biological action with oxidation and liquefaction. These solids accumulate so fast and the oxidation and liquefaction is so much slower that the interstices of the sand become filled with small particles. This condition hinders the free circulation of air and checks the passing of sewage into the sand. Ample oxygen must be provided in order that desirable aerobic bacterial changes will take place. The underground drainage must have sufficient capacity to remove the sewage as fast as it is applied to the filters. When intermittent sand filters are operating properly, the effluent will be clear and free from suspended matter.

Conclusion

From the foregone brief discussion of the principal methods of sewage treatment, the activated sludge method of treament is the most advantageous for the reasons that the impurities are rendered non-putrescible and the liquid is well clarified after passing through the settling tank which facts are of fundamental importance in the preparation of sewage for irrigation and the sewage solids for use as fertilizer.


Population Estimate Los Angeles City
From Special Sewage Disposal Commission.
George W. Fuller George C. Whipple
William Mulholland.
Population
Millions
3
2
1
1920
1930
1940
1950
Year

The city engineer of Los Angeles recommended that an intercepting sewer be constructed from the junction of Arlington Avenue and Exposition Boulevard westerly to the vicinity of Moynier Lane and Ballons Creek This sewer will provide for the excess flow in the present outfall sewer and the unsewered district in West Los Angeles and Hollywood. This cost is estimated at $1,304,000.

An activated sludge plant of 6,000,000 gallons daily capacity with location in Southeastern part of the City and provision to discharge the clarified effluent into the Los Angeles River. The cost is estimated at $488, 100. An intercepting sewer to deliver sewage to this plant from the east side of the Los Angeles River. Cost estimate $397,000.

A fine screening plant of 54,000,000 gallons daily capacity at Hyperion to remove suspended matter from the present outfall sewer. This cost estimated at $34,300.

The total cost as submitted by the engineer is $3,450,000. He also estimates that the total yearly cost of operation and maintain- ance is $258,300.

Recommendations

In putting forth the following recommendations, it must be understood that all calculations in reference to sewage flow, installation costs of treatment tanks, operating costs, etc., are based upon the estimated population of the city which while indeterminate to a certain degree gives a very good basis for determining relative costs.

1. An interceptor should be constructed to provide for the unsewered districts of West Los Angeles and Hollywood and to relieve the over- taxed system. This interceptor should extend from Arlington Avenue to the neighborhood of Moynier Lane, north of the Baldwin Hills, the capacity of which should be 190, million gallons per day.

2. A second interceptor or system of interceptors should be constructed to deliver sewage from the East Side of the Los Angeles River to a treatment plant in the Southeast part of the city.

COST OF OUTFALL SEWER

Year	Cost	Interest	Daily Flow Million Gallons	Cost of Screens	Interest	Cost of Screen Operation
1922	$14,000,000		51	$300,000		$37,200
1923		$630,000	70	105,500	$13,500	51,100
1925		1,260,000	81	61,100	36,500	59,100
1928		1,890,000	98.5	97,200	63,000	64,500
1930		1,260,000	114	86,100	50,700	83,300
1933		1,890,000	138	133,200	87,800	100,800
1935		1,260,000	158	111,000	70,500	115,200
1938		1,890,000	186.5	158,200	120,800	136,000
1940		1,260,000	207.5	116,600	94,600	151,300
1943		1,890,000	246	214,000	157,800	179,700
1945		1,260,000	268	122,000	116,000	195,700
1948		1,890,000	325	317,000	217,000	237,000
1950		1,260,000	356	172,000	160,000	260,000
Totals	$14,000,000	$17,650,000		1,993,900	1,188,200	1,671,900

Total Cost------ $36,505,000

The capacity of these sewer should be 120 millions gallons per day. These need not be constructed at once but may be constructed in units of 50 or 75 gallons capacity as required.

3. Activated sludge plants should be constructed at the terminals of these interceptors two years in advance of the sewage flow which will cause an overtaxed condition in the present plants. The increase expected in the sewage flow is shown in the table of relative cost attached.

4. There should be installed at Hyperion a fine screening plant with capacity equal to the capacity of the present outfall (58 million gallons per day).

In the application of this method of disposal, an inherent danger lies in the management. Conscientious engineering skill is required to keep all features operating to the best advantage with the marked variations in volume, character and temperature of the sewage and the multitude of ordinary operating difficulties. It is to be shown whether or not such a method can be successfully operated as a commercial project with a municipality in control. The fertilizer and water for irrigation produced will have to be disposed of as the law of supply and demand permits. It is to be hoped that enough revenue will be derived to so reduce operating expenses and prevent them from becoming a burden. The activated sludge treatment has such advantage over some of the other methods and there is such a promise of improving these advantages that investigation should be made and trials given.

COST OF ACTIVATED SLUDGE PLANTS

Year	Population thousands	Sewage Excess mill. gals,	Plant Installation Costs	Plant Installation Interest	Intersepting Sewers Cost	Intersepting Sewers Interest	Operating Cost	Screening Cost	Screening Interest
1922	430		$1,140,000		$3,250,000			$300,000	
1923	700	19.	660,000	$51,300		$146,300	$69,400		$13,500
1925	800	11	1,050,000	162,000		292,600	40,200		27,000
1928	900	17.5	930,000	384,500		439,000	63,900		40,500
1930	1,100	15.5	1,440,000	340,000		292,600	56,600		27,000
1933	1,320	24	1,200,000	703,500		439,000	87,500		40,500
1935	1,500	20	1,710,000	578,000		292,600	73,000		27,000
1938	1,760	28.5	1,260,000	1,098,000		439,000	104,000		40,500
1940	1,950	21	2,310,000	846,000		292,600	76,600		27,000
1943	2,300	38.5	1,320,000	1,580,000		439,000	140,300		40,500
1945	2,500	22	3,420,000	1,172,000		292,600	80,300		27,000
1948	3,020	57	1,860,000	2,200,000		439,000	208,000		40,500
1950	3,300	31		1,647,000		292,600	113,200		27,000
Totals			18,300,000	10,762,800	3,250,000	4,095,000	1,113,000		378,000

Total Cost-------$38,298,000

Comparative Cost of Outfall Sewer and Activated Sludge Plant.

In the computations of the total cost by 1950 of the two systems, the outfall sewer and the activated sludge plants, the population estimate at intervals of two or three years was obtained from a curve which was drawn from the estimates of the commission employed by the City of Los Angeles to investigate this problem of sewage disposal. This commission consisted of Mr. George W. Fuller, of New York City, Professor George C. Whipple of Harvard University, and Mr. William Mulholland, Chief Engineer of the Los Angeles Water Department.

The activated sludge plant would require an investment of about $60,000.00 per million gallons daily flow with operating costs at about $10.00 per million gallons. Intersepting sewers to supply the activated sludge plants with sewage were used in the computations as if they were to be constructed immediately with the capacity which was estimated to flow by 1950. An estimate of the cost of these sewers with a capacity necessary to take care of the flow in 1950 is $3,250,000.00. Intersepting sewers may be built to care for the flow two or three years in advance, but the unit flow cost of the large capacity sewer is very much less that of a smaller capacity sewer. The cost of pressing and drying the sludge was not taken into account as it is a question as to whether or not there will be a market for the fertilizer developed. The sludge can be used to fill in low lands or burned in incinerators as the case may be. The average sewage flow per capita was assumed at 110 gallons per day per capita, which gives ample allowance for increase due to the coming of such businesses which use great quantities of water. Interest costs was based on a rate of interest of 4½%. The cost of intersepting sewers in connection with the activated sludge plant was obtained from the estimate of City Engineer, John A. Griffin, as was also the cost of screens to be installed at the terminal of the old outfall sewer at Hyperion. The cost of the New Outfall sewer was taken at $14,000,000.00 with a cost of operating for the screens at $2.00 per million gallons as obtained from Metcalf and Eddy.

Bonds for the project should be floated with date of maturity, at the most, thirty years hence. The amount of money required by the bonds are shown at regular intervals in the accompanying table. The cost of floating the bonds was neglected in all computations.

Conclusions.

The relative cost of the activated sludge plants and the system of outfall sewers will be practically the same for a period of thirty years. In 1950, the total cost of the activated sludge plants will be in the neighborhood of $38,200,000.00 as against a total cost of about $36,500,000.00 for the outfall sewers.

The cost of the activated sludge method would not be such a burden upon the tax payers as the bonds are extended over a long period of time, which and the additional expense of new units come only at a time when they are needed. In case the population did not come up to expectations, the loss due to the more adequate capacity of plants than needed would not be great for after a few years it would be essential to have them.

Efforts should not in the least be lessened in investigating new types of treatment, but the activated sludge process seems at the present time to be the more logical and the more economical for the sewage flow of the City of Los Angeles.