I.C. CAMP

interceptor study for laguna lake development authority, philippines

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INTRODUCTION

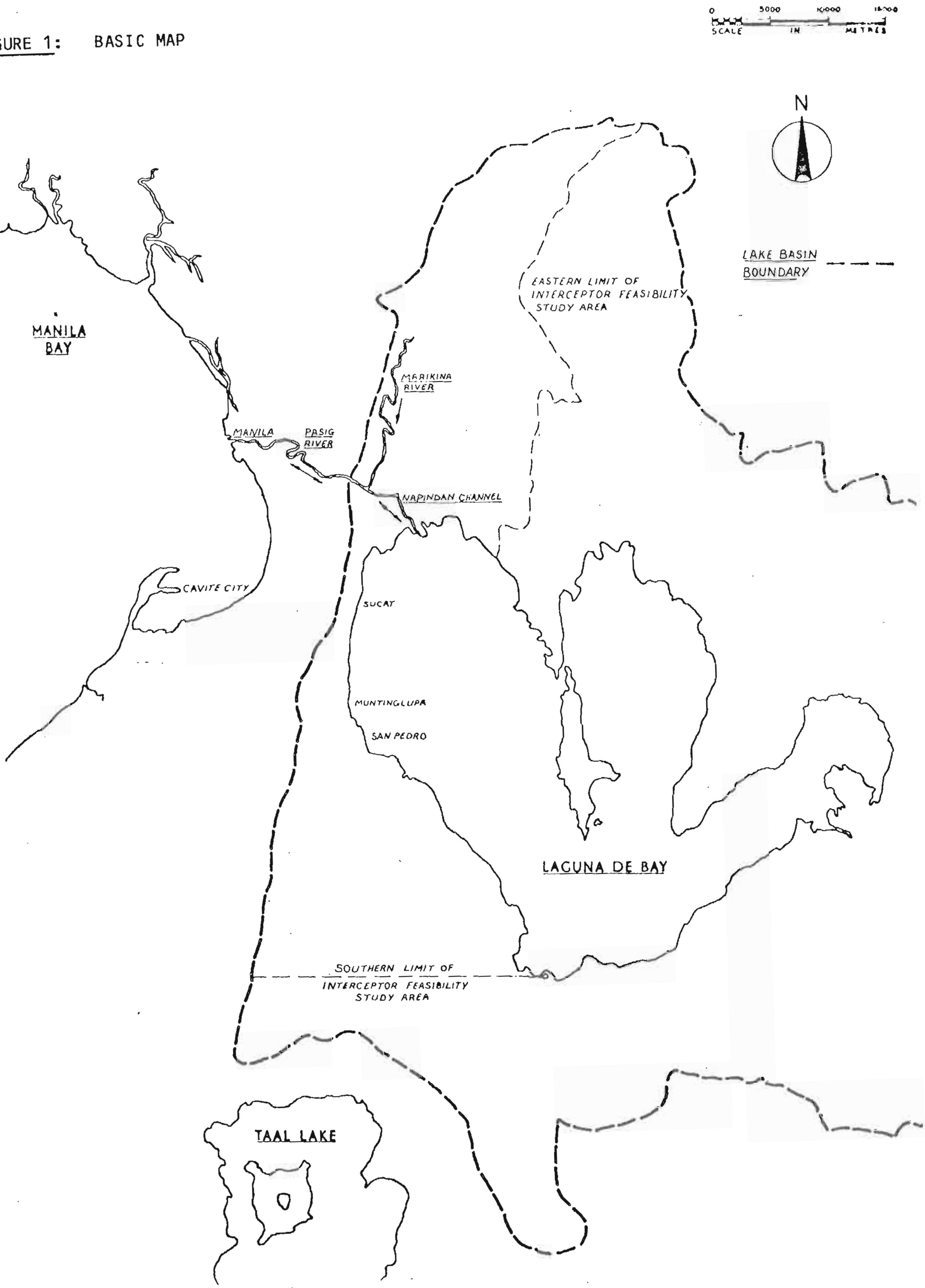
Manila, the capital city of the Republic of the Philippines, is one of the many fast growing areas of Asia. The present population is about 6 m and by the year 2000 is expected to have reached 16 m.

The central area is already densely populated and development is spreading along the coast of the very fine and extensive Manila Bay; also development has spilled over the inland ridge into the catchment of Laguna de Bay which is situated about 15 km east of the centre of Manila. Figure 1 shows the relationship between Manila, the Bay and the Lake. Important features of the area are the Pasig River, the Marikina River and Napindan Channel which are also shown in the figure. Their influence will be referred to later.

The supply of potable water for Manila has always been a major problem owing to expansion of the supply system lagging behind the increasing domestic and industrial consumption; previous studies by others have identified supply sources which might be developed as part of a long-term on-going expansion programme.

One of the sources so identified is Laguna de Bay. Aware of the potential benefit of this natural resource to the country, the Philippine Government created the Laguna Lake Development Authority (LLDA) in 1966 to conserve and develop the resources of the Laguna de Bay Region. The LLDA's powers were further strengthened by the Government in 1975 so that they could better control development within the catchment of the lake basin and minimise pollution of the lake consistent with the requirement for its use for fisheries, irrigation water (for lake-side agricultural areas) and for potable supplies.

FIGURE 1: BASIC MAP



LAGUNA DE BAY - PRELIMINARY STUDIES

Laguna de Bay, the largest lake in the Philippines, is a shallow body of water with a surface area of 900 sq km. Its average depth can vary from about 2.8 m at the end of the dry season (in April/May) to 4.8 m or more towards the end of the wet season (November/December). Owing to its shallow depth, particularly in the dry season, wind-induced water movement stirs up the light bed sediment such that the lake water is always turbid, frequently looking like weak milk-coffee.

In 1968 it was concluded in a report(1) to the NWSA that pollution existed at isolated parts of the lake but at that time it was said not to be widespread and did not constitute a problem. With industrial development of the lake-shore and expected population growth, it was considered that pollution could become a problem in the future.

One major source of pollution comes from the Pasig River which, at certain unfavourable conditions of tide in Manila Bay and lake water level near the end of the dry season, can reverse its direction of flow and discharge saline water, itself containing a very heavy pollution load from Manila, into the lake. It was suggested in the report that some form of hydraulic control might be feasible, not only to prevent back flow of the River Pasig into the lake, but also to eliminate the frequent and prolonged flooding in central Manila; the latter is due to the inadequacy of the River Pasig to pass peak floods from the Marikina River and the lake catchment whose only outlet to the sea is via the Napidan Channel and River Pasig.

As a result of those studies the Government is about to embark upon the construction of the Hydraulic Control Structure across the Napindan Channel - to prevent back flow of Pasig River water into the lake, the Mangahan Floodway - which would take the Marikina floodwaters into the lake thereby minimising flooding in the centre of Manila, and the Paranaque Spillway - which will serve as an emergency outlet for the lake to Manila Bay so that lake-shore properties and agricultural areas would not be flooded in the wet season. These projects are shown in figure 2.

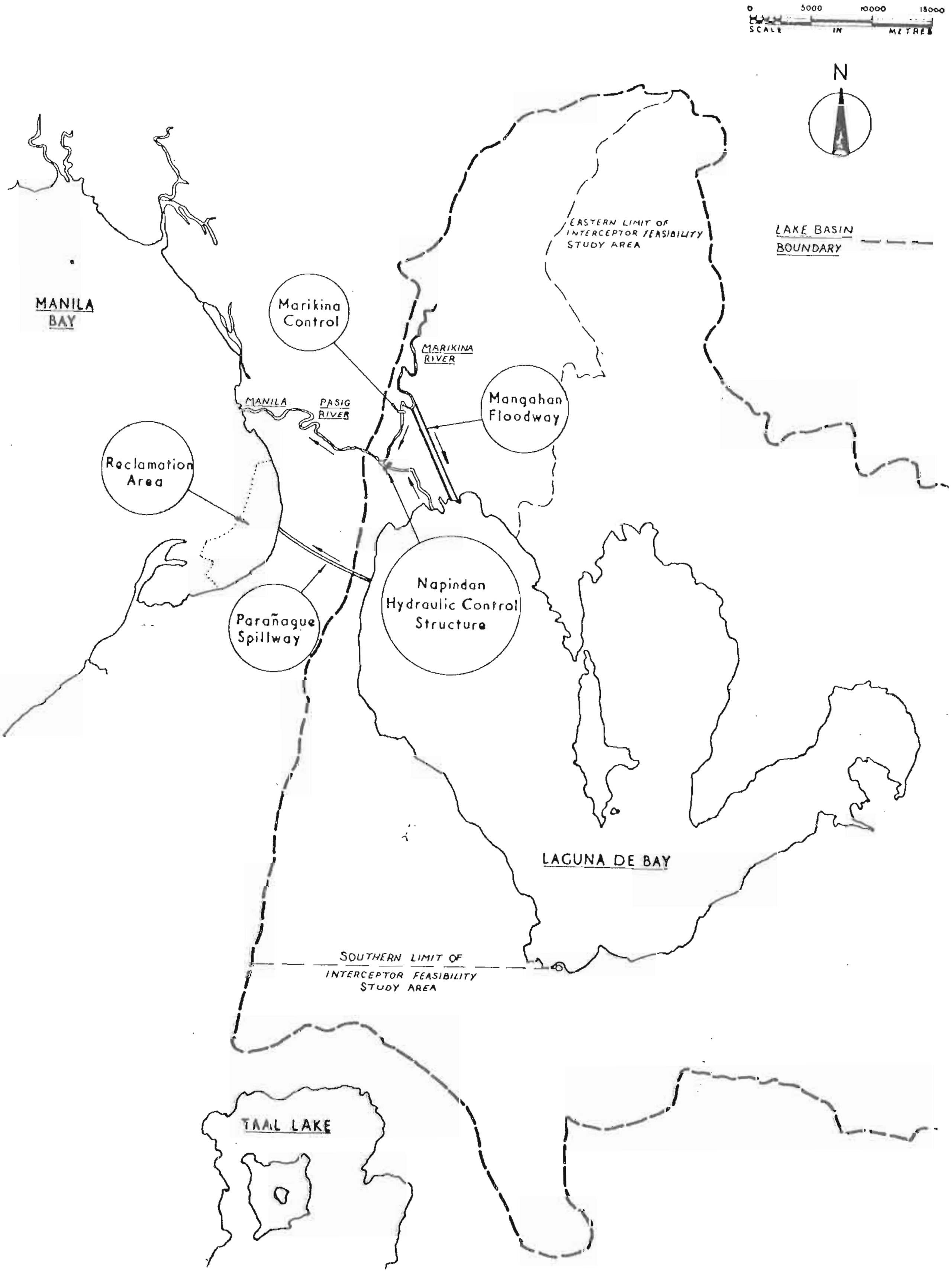
At the conclusion of these works and if no other action is taken, the lake could be receiving the untreated wastes from about 2.5 m population, and from an extensive and mixed industry. Owing to overspill development gaining momentum particularly along the western and northern shores of the lake, it is predicted that by the year 2025 the lake catchment population could have risen to 5.3 m.

Between 1967-1969 a Master Plan study(2) of the Manila Metropolitan area for the WHO embraced part of the Laguna de Bay catchment; the study report set out proposals for sewerage and temporary sewage disposal facilities, the phased construction programme leading to the establishment of a trunk Pasig sewer and outfall to Manila Bay.

Within the area studied, many of the properties had individual, or were connected to, communal septic tanks but as emptying was seldom undertaken the effluent overflow to adjacent surface water drains, channels or ditches was as strong, if not stronger, than crude sewage, a situation which still pertains.

Relative to the more pressing needs of the Manila Central Area, the lake shore and Marikina valley sewerage were considered low priority. However, as a result of the subsequent lake water study(3) the need to control pollution of the lake, in association with the Mangahan Floodway and the Napindan Hydraulic Control Structure, was re-emphasised. The Laguna Lake Development Authority therefore commissioned JD & DM Watson to make a more detailed Interceptor Feasibility Study comprising an evaluation of the pollution problem and its solution; a final report in draft has now been submitted to the Authority by the consultants.

FIGURE 2: HYDRAULIC CONTROL PROPOSALS



INTERCEPTOR FEASIBILITY STUDY

Objectives

An interceptor is usually thought of as a sewer laid to take flows from existing lateral sewers and to convey them collectively to some other point for disposal. For the purposes of this study the term relates to the interception of liquid wastes however conveyed so that they could be discharged either into Manila Bay or to the Lake, with or without treatment as might be found necessary.

Much of the previous study material formed a useful starting point in the collection of basic data but with such a rapid increase of population and industrial development within the study area (shown in figure 3), updating was an unavoidable task. Because of the changed circumstances and the possibility of future changes in the type and location of development, it became abundantly clear that the interceptor system would have to be designed with maximum flexibility in mind.

In the special case of waste discharged to Laguna de Bay, it was necessary to consider nutrients, organic load (BOD), suspended solids, toxins and bacterial contamination.

a) Nutrients pose a special problem; further studies are in progress in an endeavour to more positively establish the limiting factors in lake eutrophication.

b) Calculations show that, so far as BOD is concerned, if dispersed uniformly over the lake there is adequate oxidation capacity to deal with the sewage in the crude state. However, dispersion in this manner is not feasible.

c) Toxic substances in industrial effluents must be strictly limited by partial or complete removal before the effluent is discharged to the lake so as to protect fisheries and man.

d) Percentage reduction of bacterial organisms in conventional treatment works is very high although the remaining numbers are significant; exposure to sunlight effects a further reduction in numbers.

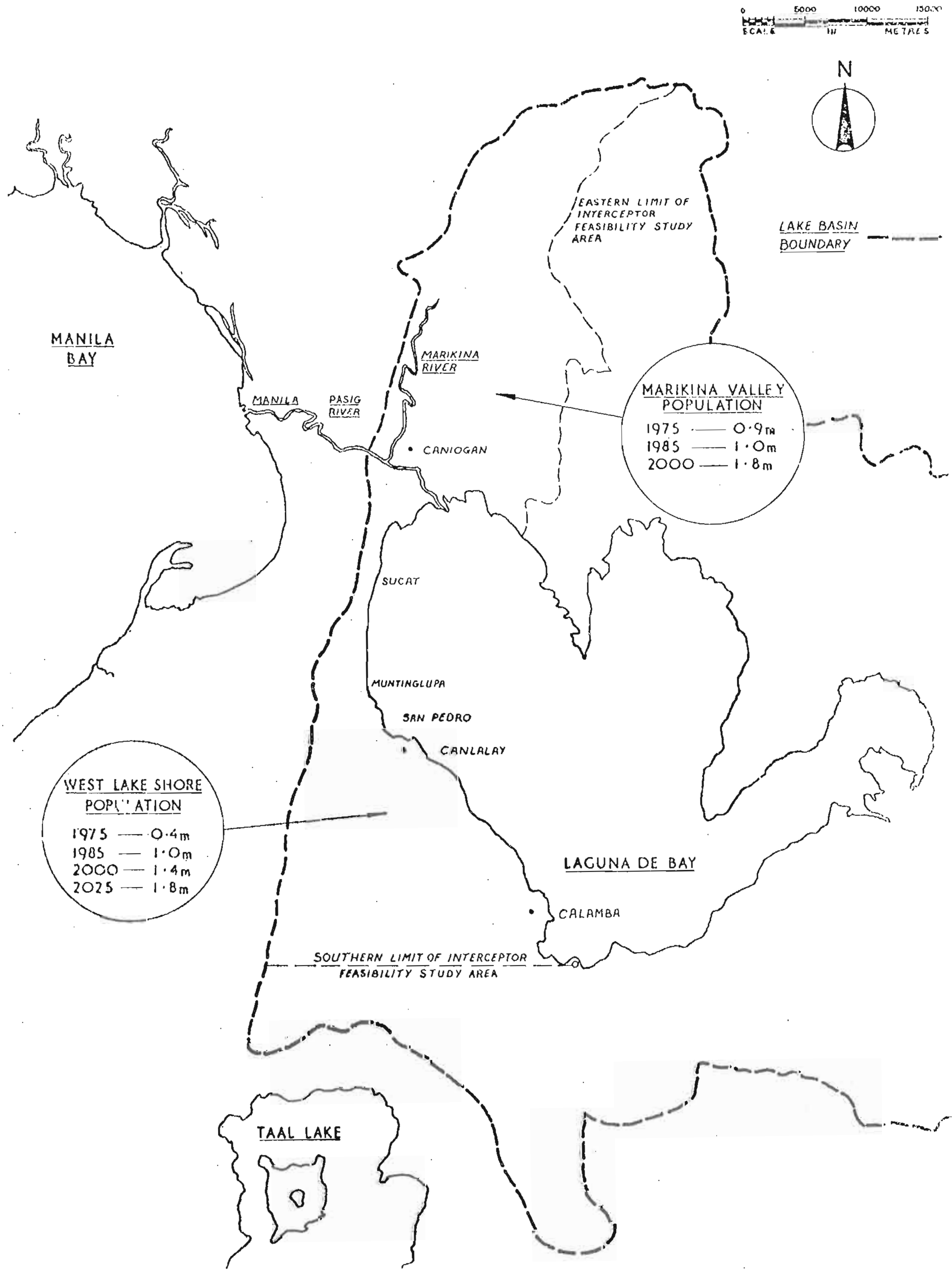
Water quality standards

The Philippine National Pollution Control Commission in 1966 promulgated classification and water quality standards for fresh water; the regulations are now under review and careful consideration is being given to sensitive waters, such as Laguna de Bay, the Marikina and Pasig Rivers.

Even in their 'natural state' rivers, lakes and seas are subject to contamination from vegetable and animal debris, soil particles, chemicals dissolved in ground and other waters, and other 'pollutants'. All natural waters have a capacity for self-purification which results in oxidation, assimilation or stabilisation of polluting substances by chemical and biological means; this capacity may be diminished if the polluting load is excessive or if toxic conditions occur. The disposal of domestic sewage and industrial liquid waste normally and economically takes place to natural water courses contributing to the water cycle, eventually reaching the sea, but it is necessary to control the volume and nature of polluting discharges to ensure that the loads applied are within the capacity of the receiving water.

It may be convenient and economic to reduce the pollution load in a treatment works or alternatively to convey the flows to a point where more

FIGURE 3: DEVELOPMENT GROWTH PREDICTIONS



dilution is available, and in consequence the capacity for self-purification is enhanced. The use made of the water downstream of the discharges is also relevant, and special care needs to be taken of water used as a source of potable supply or for recreation. For fresh water streams and rivers, the available dilution can be ascertained and the effect of the diluted waste on the biological system and the rate of self-purification assessed. For marine discharge conditions, the available dilution is potentially very large and the main concern is with conditions near the discharge point, necessitating measurements and prediction of water movement and waste dispersion.

Natural waters normally contain significant amounts of oxygen in solution; the equilibrium or 'saturation' value depends on temperature and salinity. Chemical or biological oxidation is an important means of purifying or stabilising many pollutants and depletes the oxygen level, but this is offset by replenishment, mainly from the atmosphere and, depending on the rate of oxygen demand, a dynamic balance may be struck at a level less than saturation.

In previous studies of the lake attention has been drawn to nitrogen - and its role in eutrophication - and to the harmful effects of toxic substances. It was suggested(4) that, from the studies carried out in 1973, the total nitrogen input to the lake should be limited to 5000 tonnes a year and that, so far as domestic sewage was concerned, this objective could be achieved by the provision of an interceptor along the west shore of the lake from San Pedro to Sucat to collect and export to Manila Bay the industrial wastes of the most industrialised area along the lake shore, and the municipal waste from San Pedro to Muntinglupa. It was also assumed that the Marikina Interceptor would discharge the northern area to the Pasig River. It was further said that sewers and lagooning facilities must be progressively built between 1990 and 2000 to serve the predicted 1 m total future inhabitants in the cities around the lake shore. It was stated that the population projection for the year 2000 was 2.8 m; thus the wastes from about 1.8 m were to be diverted to the Pasig River.

Events have significantly overtaken the projections made in 1973. At the present rate of growth, the 2000 year population will be reached by 1985, if not earlier, continuing to rise to about 5.3 million by 2025.

Thus the scale of the task has dramatically altered, not only in the volume of sewage to be collected, but a greater degree of treatment would have to be given to all of the flows to achieve the same lake water quality objectives. Pending the formulation of a comprehensive set of standards applicable to the whole country, the Interceptor Feasibility Study Consultant has suggested that any effluent discharged to the lake should contain not more than 30 mg/l SS and 20 mg/l BOD. A process would also need to be chosen to give good denitrification.

It was envisaged that as the initial stage of construction would comprise approximately 25% of the foreseeable future requirements there should be scope for subsequent effluent improvement (biologically and bacteriologically) so as to minimise initial capital expenditure. So far as discharge to the Pasig River is concerned - for long known as 'the dead river' - maximum benefit would be derived by first improving the upper reaches of the river so that, by having a reserve of dissolved oxygen, lower reaches of the river could more readily assimilate some of the wastes aided by the natural processes of self purification. Thus if the initial phase of construction is to have a discharge to the head of the Pasig River, it should also be well nitrified and to a 30 mg/l SS - 20 mg/l BOD standard.

Alternative solutions

From a consideration of the topography of the Marikina Valley, the logical development of the valley sewerage system would be to bring all sewage to the southern end near Caniogan and to discharge treated effluent into the Pasig River for dilution and conveyance to the sea via Manila Bay. Owing to the congested development near the confluence of the Marikina River, Pasig River and Napindan Channel, direct discharge to the Pasig River would be expensive. Thus the initial phase of construction would allow effluent discharge into the Napindan Channel, the hydraulic control being so arranged that it is taken with a small flow into the Pasig River from the lake most of the time.

The west lake shore with its present concentration of industry and residential property being expanded southward presents the option of treatment to a high quality and discharge to the lake or treatment to a lesser standard and discharge to the Manila Bay. As the concentration of population and industry in the southern portion of the study area increases, determination of the best location for an outfall, or outfalls, is governed by land availability for construction, effluent re-use in such a manner as results in further purification, and evaluation of the engineering aspects of alternative schemes of sewerage and sewage treatment.

Consideration of these factors has led to the selection of the Canlalay and Calamba areas as possible works sites, a single aerated lagoon/oxidation pond unit being provided at each and a twin module aerated lagoon/oxidation pond unit at Caniogan, each module to have a dry weather flow capacity of 100 000 m^3/d. Thereafter, development in the respective catchment would dictate the type and location of facilities additional to those provided in the first phase of construction.

Stream and river intakes

In the absence of a conventional sewerage system, all liquid wastes generated in the catchment which do not evaporate or become absorbed in the soil (extensive use being made of the polluted streams and rivers for land irrigation) eventually find their way into the lake and the Marikina River via the many streams and rivers.

Thus to intercept pollution at minimum of expense the lake shore interceptors and other trunk sewers must be arranged to accept as much of the stream and river flow in the dry season as may be feasible, acknowledging that during the wet season a much diluted pollution load will have to pass forward to the lake until such time as a full sewerage system is available. The stream and river intakes thus become a vital part of the first phase of construction.

Any structure placed in a river system alters its regime and smooth transition into and out of the structure is essential; over-topping must also be controlled. If any of these features disturb the regime, the river may quickly take a new course around the structure.

Regarding the intakes, the major operational problem to be overcome is the prevention of large objects entering the sewers. A conventional bar screen, if not frequently raked, would rapidly clog and prevent interception. Raking could be undertaken manually or mechanically but the former would require almost continuous manual attendance. Mechanically raked screens would require no more than perhaps two visits each day to remove the screenings to the disposal point and to generally check the equipment.

It is considered feasible to devise a non-conventional manually raked screen which would require no more visits than for a mechanically raked screen, but attendance time for raking and disposal of the screenings would be greater. However, as transport of debris in rivers is influenced by the characteristics of the regime and wind conditions, there is no guarantee that identical intake screen arrangements in different locations will operate with equal efficiency.

The draft proposals allow for collapsible gates to be provided where the weir level has to be located below the lake's top water level of 12.5 m above LLDA datum. This feature keeps the lake water out of the river but in times of floodflow allows the river to discharge without over-topping its banks. The added advantage of this system is its capacity to hold a small 'first flush' storm flow within the river basin and for it to be drained into the interceptor as required.

Sewerage

Route selection was based upon many visual inspections on the ground, check line and levels surveys over the majority of the selected routes, supplemented by two visual reconnaissances (at three month intervals) by helicopter and recorded in 210 photographs. Very detailed 1/10 000 scale maps had been prepared some years previously by the Bureau of Coast and Geodetic Surveys, but the rapid growth of development meant that every detail had to be checked.

The long term proposals provide for wasteflows from the population, industry and livestock expected by the year 2000. Such a system could be achieved through a programme of expansion both of the trunk sewers and the reticulation of small sewers conveying wasteflows from individual properties to the trunk sewers. However, the major problem facing the LLDA is the one of ensuring that routes now selected for trunk sewers are still available at the future construction dates.

For reasons of economy in capital and running costs, it is desirable that future drainage should be on the 'separate' system, i.e. where a two-pipe system is provided, one exclusively for all liquid wastes and the other for surface water run-off from roads and paved areas.

Except at considerable and unnecessary expense to prevent it, infiltration will occur in the sewer system. By infiltration, we mean the entry of ground water through defective joints and leaks in damaged pipes forming the whole system comprising interceptors, laterals, reticulation system and house drains. The act of constructing sewers and drains opens the ground and unless exceptional backfilling methods are carried out, ground water usually finds its way into the backfill material. Thus, assuming the water table is high enough, the degree of infiltration is a function of the care and skill with which the pipes are made and laid.

There is no doubt that the art of pipe manufacture and pipe laying in the Philippines is improving. As major projects come forward for implementation it will be necessary for the improvements to continue so that locally manufactured pipes are available with flexible joints and, where necessary, surfaces resistant to corrosion arising from liberation of hydrogen sulphide from septic sewage.

So far as concrete pipes are concerned, specialised manufacturing techniques are required for pipes of more than 2 m diameter. Consideration of various alternative solutions of sewerage and sewage disposal indicated that some schemes might require pipe diameters of 4.5 m. However, the early years of operation with large sewers and relatively low flows - hence low velocities - would lead to unacceptable deposition of solids and increase in septicity. In the review of all the factors it was concluded that the maximum size of the initial phase sewers should be limited to 2 m internal diameter.

Concurrently consideration of sewage treatment requirements and phased development led to the conclusions that which ever form of treatment was to be adopted, the module size should be based upon a dry weather flow rate of 100 000 m^3/d. Assuming a separate sewer system and from an analysis of the probable distribution of domestic and industrial wastes, infiltration and flow balancing effects in a large sewerage network, it was concluded that the peak flow rate into a standard size module would be about 270 000 m^3/d.

Quite fortuitously, this is also the carrying capacity of a 2 m diameter pipe laid at a gradient to give satisfactory velocity flowing full of 1.0 m per second, the hydraulic design based upon the Colebrook-White equation and 'K' factor of 1.5 mm.

Sewage treatment

In the initial period of operation when the majority of the inflow to the treatment works will be from polluted streams and rivers, the sewage strength will be weaker than that from a conventional sewerage system owing to dilution from the natural stream and river flow but clearly the latter will be at a minimum during the dry season.

In the long term liquid wastes must be taken into the system direct so that the volume to be treated and pollution of surface waters are minimised. It is suggested that priority should be given to the connection of major industrial wastes because, as large point sources, collection is more easily and economically achieved than the same volume of domestic wastes. However, whilst the objective is to collect all wastes, those that are not biodegradable may have to be pretreated at the manufacturers premises before discharge into the communal system.

From 1970 to 1976 the number of industrial premises appear to have more than trebled; the recent assessment gave the probable number at 460 of which 16 have pretreatment plants. The LLDA has now to decide upon its future course of action; insistence upon construction of more pretreatment plants which might become abortive in perhaps five years time may no doubt appear to the industrialists concerned as unnecessary expenditure and cause for annoyance but some measure of control has to be effected to protect the lake (which is already in use for fisheries and agriculture) pending commissioning of the interceptor system. Thus there is some latitude for accepting a compromise solution in the interim giving maximum overall benefit in the future. This ideal solution should be the objective but it may be hard to achieve in practise; every case has to be judged upon its own merits.

The tropical conditions in the Philippines favours low-cost treatment processes by oxidation ponds, but for the population involved, a very large land area would be required. Draft layouts suggest that land areas of about 1.0 ha would be required for a dry weather flow of 1000 m^3/day.

The major operational problems with natural oxidation pond are: unreliable performance in terms of effluent quality, smell and control of mosquitoes. For these reasons the pond system was discarded in favour of a more controllable system comprising surface aeration in a 5 m deep lagoon having 4 days retention followed by two 1.5 m deep oxidation ponds in series, each having 3 days retention (at 1 dwf). The lagoons would be preceded by mechanically raked screens and spiral flow grit channels. Land area requirements reduce to about 0.6 ha for a dwf of 1000 m^3/day.

It is envisaged that if development continues at the predicted rate additional treatment facilities would be required either in the form of aerated lagoons/oxidation ponds or, where space limitations preclude their use, conventional activated sludge units with the facility for significant nitrogen removal. An alternative solution but requiring greater capital resources would be to provide screening and settlement followed by a long land line and outfall to Manila Bay.

For economy of construction and compatibility, discharge to Manila Bay should be considered in conjunction with disposal of sewage from the seaward side of Manila. Previous marine studies indicated areas of feasibility but the proposals will have to be reviewed taking account of the very significant reclamation work which is presently taking place in Manila Bay.

For the subsequent phases of construction the design data will require revision based upon experience gained in the operation of the previous phases and prediction of future conditions. So far as domestic wastes are concerned, the load discharged to the sewers will depend upon the extent to which the reticulation system is developed and nature of the residential development served. It is estimated that in the unsewered areas only about 25% of the domestic pollution load reaches water courses; some of this load may be subsequently absorbed in land irrigation schemes before the flow reaches the interceptors via streams and river intakes.

Livestock in the study area includes pigs, poultry, ducks, quail, cattle, caraboas, horses and some goats. The principal animals of concern are pigs and to a lesser extent poultry. In commercial establishments it is envisaged that animal wastes removed from pens during daily wash-down procedures would be passed to pretreatment units to halve the pollution load discharged to sewers. Livestock wastes account for about 0.5% of the flow but about 25% of the pollution load, but reducing to about 12.5% by the end of the century.

Agricultural wastes will remain a source of pollution on the lake as their collection and treatment would be prohibitively expensive. Thus very close control over the use of fertilizers and pesticides is required.

MANAGEMENT AND FINANCE

The successful implementation of the project will be heavily dependant upon the adequate manning of the system and in the raising of finance for capital and running costs.

Management aspects include the control of all types of development within the lake catchment, supervision of sewerage and house connections to ensure that surface water is kept out and that infiltration is minimised, control over agricultural wastes and the use of fertilisers and pesticides, establishment of a procedure for rapid clearing of oil spills and harmful chemicals, operation of the system and staff training.

Policy decisions have yet to be taken by the LLDA regarding financial aspects of the proposals. If the scheme is considered as a social project it might be argued that its cost should be recovered within the country's general taxation arrangement. At the other extreme, a charge might be levied on every user. However, it seems that the correct solution may be somewhere between the extremes.

It would be misleading to quote the estimated costs of the project as the initial phase of construction does not include lateral sewers nor house connections, but in the long term the capital expenditure could be within the range 100-120 US dollars per person served by the system (at present day prices).

ACKNOWLEDGEMENTS

The Author is most grateful to the Laguna Lake Development Authority for permission to present this contribution to the conference and acknowledge the great help and encouragement received from the Authority's officers and staff during the Interceptor Feasibility Study. Acknowledgement is also made for the assistance given by the Philippine Government and Asian Development Bank.

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