consideration. As already mentioned, the level of sewerage service charge and the value of FIRR are both not appropriate in evaluating the alternatives.

3) Sensitivity Analysis

Sensitivity analysis was performed for the Proposed Plan. Four (4) cases were presupposed as shown here under:

(Unit: %)

Cases	O/M Costs	Capital Costs	Revenue
Base Case	-	-	-
Case (1)	+ 20	-	-
Case (2)	-	+ 20	-
Case (3)	+ 10	+ 10	- 10
Case (4)	-	-	- 20

The delay in project implementation was not considered in establishing cases because it does not constitute a negative factor for the project.

Results of sensitivity analysis are presented below:

(Unit: %)

Cases	FIRR (a)	Annual Interest Rate (b)	Commission Charge (c)	Difference (d = a - (b + c))
Base Case	13.3	5.25	0.25	7.8
Case (1)	11.7	5.25	0.25	6.2
Case (2)	9.5	5.25	0.25	4.0
Case (3)	7.4	5.25	0.25	1.9
Case (4)	6.7	5.25	0.25	1.2

Note: Commission charge = commission charge of BANOBRAS for the first five years of repayment

The above table indicates that the Proposed Plan will be able to maintain its financial equilibrium under any conceivable adverse circumstances including cost overrun and revenue shortage.

2.4.4 Urgent Project

The afore mentioned financial analysis is for overall project including the Urgent and Final Projects. In this section the financial analysis for the Urgent

Project will be described. The financial analysis is carried out only for the Proposed Plan.

The initial costs of the Urgent Project are estimated to be N$ 1,392.1 million. The annual O/M costs are estimated to be N$ 83.7 million after the completion of the Urgent Project.

Financial resources for the initial costs are assumed to be fully covered by external agency A. The afore-mentioned preconditions and assumptions regarding the recovery of costs, depreciation period, period of projection, rate of tax on corporate income and collection efficiency of bills apply to the Urgent Project.

Supposing the Urgent Project is itself the final project, then the proposed sewerage service charge will be as follows:

Unit: ($N\$/m^3$)

Area	Sewerage Service Charge
Federal District	0.265
Mexico State	0.262

The projected financial statement is shown in Table I.15. The table indicates that the wastewater treatment plant will be managed financially well from the long term perspective.

The cost benefit streams were prepared to estimate FIRR as shown in Table I.16. Using the Table FIRR was calculated at 10.6 %. It is greater than the annual interest rate of 5.25 % plus the BANOBRAS commission charge of 0.125 % to 0.25 %.

The total amount of repayment was calculated as shown below:

(Unit : N$ million)

Alternative	Initial costs at 1994 Prices	Repayment Costs at Current Prices	Repayment Costs at Present Value
Proposed Plan	1,392.1	2,172.5	883.7

Repayment Costs at Present value were calculated by dividing repayment costs at current prices by OCC (10 %).

Sensitivity analysis was conducted for four (4) cases as shown in the table in the preceding section 4) of 2.4.3. The results are summarized hereunder:

(Unit: %)

Cases	FIRR (a)	Annual Interest Rate (b)	Commission Charge (c)	Difference (d = a - (b + c))
Base Case	10.6	5.25	0.25	5.1
Case (1)	9.4	5.25	0.25	3.9
Case (2)	8.5	5.25	0.25	3.0
Case (3)	7.2	5.25	0.25	1.7
Case (4)	6.8	5.25	0.25	1.3

Note: Commission charge = commission charge of BANOBRAS for the first five years of repayment

The above table reveals that the Proposed Plan can keep up its financial equilibrium under any conceivable adverse circumstances including cost overrun and revenue shortage.

3. Institutional Aspect

3.1 Overview of Institutional Matters in Water Sector

3.1.1 Current Administration and Water Sector

The Current administration introduced the basic philosophy of economy (that is, efficient use of resources), economics (that is, generation of sufficient revenues to meet costs) and environmental protection into the water sector.

The administration stressed importance of the provision of water supply and sewerage services in raising people's living standards and health. In the urban centers, the reduction of demand, the expansion and improvement of service, the treatment and reuse of wastewater and the replacement of clean water with treated water in agriculture has been stressed.

The aim is that tariff will recover the costs of the investments, the operation, the maintenance and rehabilitation of the service systems. Simultaneously expansion of the proper resources of the sector, increase in the efficiency of the water usage and change in the notion about the value of water has been emphasized. For manufacturing industries replacement of clean water with treated water has been promoted so as to make it necessary for pollution generating industries to have treatment facilities.

In other words participation of private, public and social sectors in the financing of water treatment systems has been encouraged.

The administration propelled the decentralization of various phases of the provision of water supply service and promoted the perfect fulfillment of the responsibility of municipalities. In this sense, it offered supports to the municipal operation organizations so that they could effectuate self-financing measures and optimize the use of water. These measures include the gradual lifting of tariffs to adequate levels, installation of meters, treatment of water and reduction of leakage.

3.1.2 Important Institutional Issues

The enforcement of various relevant laws including the Law of National Water and reinforcement/creation of organizations concerned including CNA reflected the policy of the current administration toward the water sector.

What the administration aimed at, as mentioned above, are not fully realized yet and several items remain the urgent and major concerns of relevant government organizations.

JICA Study Team has studied such items and are described below.

1) Raising of water tariffs

DGCOH is budgeted to recover 57.5% of its O/M costs in 1994. In the case of CEAS the recovery ratio was 71.8% in 1993.

These figures shows the lingering notion that water service is a social service and it is not proper to regard it in economic or financial terms. But, now the basic philosophy toward the service has changed world-wide and Mexico followed suit.

The analysis of the position of water charge in household income and the results of the sampling questionnaire surveys regarding the willingness to pay for water supply / sewerage service reveal that there is enough room or potential in the home economy to set aside a sum of money that will make water related organizations in the Federal District and Mexico State financially self-sufficient.

2) Introduction of sewerage service charge

The implementation of the Texcoco wastewater treatment plant provides the opportunity for the authorities to introduce a solid sewerage service tariff that will self-finance the organizations concerned.

It has been made clear by the JICA Study Team that people of the Study Area can afford to fully shoulder such sewerage service charge.

3) Real implementation and expansion of meter system

Without the installation of water meter to each client, collection of water supply / sewerage service charge accurately is impossible. In other words installation of water meter is prerequisite for the attainment of self-financing of water organizations. Also, a tariff based on the diameter of the tap makes people misuse the precious natural resource.

4) Reduction of leakage

About 30 to 40% of water produced is said to be lost through leakage before it is used by beneficiaries. High leakage led to inefficient use of water sources and led to higher water tariff.

5) Raising of water bill collection rate

At present only 60% of water bills are collected. It deals a hard blow to the financial status of water organizations and shows negligence in realizing the expensive costs invested in water facilities. It unnecessarily pushes up water tariff.

6) Introduction of strict financial management

All the above mentioned items have one common objective of improving the financial status of water organizations toward self-financing. To achieve this objective strict financial management should be introduced to the water organizations.

Long-, medium- and short-term financial plans should be formulated so that the organizations may be financially self-sufficient in the years to come. At the same time, annual financial plan should be made. Also, monthly comparison of the budget and the performance should be strictly observed and the causes of difference should be analyzed.

3.1.3 Recommended Institutional / Organizational Measures

1) Raising of water tariffs

Water tariffs of the Federal District will be revised so that the average charge per m^3 will go up to N$ 1.837 from the current estimate of

N$ 1.056. Under the new tariffs a household in the Federal District will pay N$ 36.3 per month on average.

Also, water tariffs of the Mexico State will be revised so that the average charge per m^3 will be raised to N$ 1.310 from the existing N$ 1.142. Under the new tariffs a household will pay N$ 20.5 per month on average.

2) Introduction of sewerage service charge

Financial analysis made it clear that introduction of the following sewerage service charge will make it possible for the Texcoco wastewater treatment plant construction project to recover initial, O/M and replacement costs.

The Federal District will introduce sewerage service tariffs so that the average charge per m^3 will be ultimately N$ 0.605. Under the tariffs a household will pay N$ 11.9 per month on average. The combined water supply and sewerage service charge a household will monthly pay on average comes to N$ 48.2.

Also, the Mexico State will introduce sewerage service tariffs so that the average charge per m^3 will be ultimately N$ 0.562. Under the tariffs a household will pay N$ 8.8 per month on average. The combined water supply and sewerage service charge a household will monthly pay on average comes to N$ 29.3.

3) Real implementation and expansion of meter system

If water meter is to be installed in every client as early as possible and if meter system is to succeed, it will be necessary institutionally to obligate every client to install it and to obligate every client to maintain the proper functioning of meter. On the side of water organizations it will be necessary to regularly dispatch men for the correct reading and recording of water consumption.

These aspects are already written in the law. Now it is required to put them into practice. In this regard the relevant functions/activities in DGCOH, CEAS, etc. should be reinforced.

The authorities intend to realize the captioned objective in two years time.

4) Reduction of leakage

The causes of leakage should be identified and proper measures should be taken toward the alleviation of the adverse effects of those causes.

To succeed in it, it will be necessary to provide those measures in the law and to enhance the relevant functions/activities in DGCOH, CEAS, etc. Also, the cooperation of the private and social sectors is indispensable.

The authorities are making effort to attain the captioned objective in two years time.

5) Raising of water bill collection rate

The causes of the low rate of collection should be identified and measures should be taken to rectify the situation. Such measures will include reinforcement of legal provisions whereby violators of the provisions will be punished as well as reinforcement of water organizations in terms of functions and workforce.

6) Introduction of strict financial management

Institutional and organizational strengthening is necessary to effectuate the realization of strict financial management.

For a strict financial management of a water organization the three steps cycle of plan-do-see should be strictly observed. That is to say, firstly long-term corporate financial plan should be established, whereby corporate target of investment costs, O/M costs, the sources of revenues to recover those costs, etc. should be estimated. Based on the plan medium-term, short-term and finally annual financial plans should be worked out.

Before the start of a particular financial year, the annual financial plan should be prepared and formulation of the expenditure and revenue budget should be done. Such a budget will be ultimately distributed over 12 months. This is the "plan" step.

Corporate activities such as the implementation of investment projects, production and distribution of water, transportation and treatment of wastewater and collection of water should be done. This is the "do" step.

Corporate activities not only generate revenues, but also entail costs. These should be monthly recorded, compared with the budgeted ones. Finally, the annual comparison of the accomplishments and the budget should be done and the differences between them should be analyzed. This is the "see" step.

Based on the analysis of the differences of the performance and the budget corporate financial plans should be revised in one way or another. In that way the next plan-do-see cycle will start.

For a strict observance of the three step cycle centering on the "plan" and "see" steps, these steps should be provided in the law and the organization in charge of finance should be reinforced and elevated.

3.2 Required Activities for Sewerage Organization

At the present moment there is no independent sewerage organization either in the Federal District or the Mexico State.

The activities related to sewerage are now done in parallel with, or together with those related to hydraulics in the water organizations, namely, DGCOH and CEAS.

It may be worthwhile to list the required activities for a sewerage organization so that proper structure of such an organization may be worked out. These activities are shown hereunder:

1) Corporate planning

Working out long, and medium term plans on sewerage demands, construction and replacement of sewerage facilities, revenues and costs, financial requirements and sources, personnel and remuneration requirements, etc.

Sewerage demands mean the projection of the number of beneficiaries by type (residential, commercial, institutional, industrial, etc.) by area, the volume of wastewater discharge by type of beneficiaries by area, etc.

Sewerage facilities include sewers, treatment plants, pumping stations, manholes, and property connections.

For the planning of revenues one needs the detailed planning on the number of beneficiaries, the volume of wastewater, sewerage service tariffs and charges, collection efficiency, etc.

For the planning of costs one needs the detailed planning on O/M costs, depreciation, payment of interest, etc.

For the planning of financial requirements and sources one needs the detailed planning on construction/replacement costs, repayment costs, self-financing, loans, subsidies, etc.

For the planning of personnel and remuneration requirements one needs the detailed planning on recruitment and assignment, training, basic salaries, incentives, retirement benefits, etc.

2) New works

Conducting the technical research, planning, designing and construction of sewerage facilities, and the implementation of contracts.

3) Water pollution control

Implementing wastewater discharge standards and monitoring effluents quality. Wastewater discharge standards should be implemented step by step and steadily. Monitoring of effluents quality should be done regularly and without fail.

4) Sewerage operation and maintenance

Carrying out the operation, maintenance and inspection of sewerage facilities, operation of workshop, and keeping of technical records. Technical records include records of construction plans, property connections, operations, maintenance, repair and replacement.

5) Administration and finance

Performing the functions such as personnel and general administration, financial management, accounting, public relations and internal audit.

Personnel and general administration includes secretarial/clerical, storage, personnel, purchasing, training and legal functions and activities. Financial management includes the formulation of short-term and annual sewerage facilities investments, revenues, costs and funds plans, the preparation of annual and monthly revenues and costs budget, comparison of the accomplishments with the budget on monthly and annual basis, analysis of the differences between the accomplishments and the budget, preparation of the recommendations on the remedial steps to resolve the differences, etc. The recommendations will be reflected in the new corporate planning.

3.3 Existing Organization

The existing functions/activities related to sewerage are performed by DGCOH for the Federal District and by CEAS for the Mexico State. The structures of the two (2) organizations are shown in Appendix D, Fig. D.6 and Fig. D.7.

Functions/activities in the two organizations can be divided into three categories, namely, those related to water supply, those related to sewerage and those related to both.

DGCOH is composed of 6 directorates, namely Technical Directorate, Directorate of Construction, Directorate of Operation, Directorate of Maintenance, Directorate of Hydraulics and User Services, and Directorate of Hydraulic Operation and Support Services.

The requirements of a sewerage organization were listed in itemized form in the preceding section. One observes that "corporate planning" functions are performed under Technical Directorate, "new works" activities are carried out by Directorate of Construction, "water pollution control" functions are performed by Technical Directorate, "sewerage operations and maintenance" activities are carried out under Directorate of Operation and Directorate of Maintenance, and "administration and finance" functions are incorporated in Directorate of Hydraulics and User Services, and Directorate of Hydraulic Operation and Support Services.

It appears that the existing organizational structure of DGCOH satisfies the general requirements of a sewerage organization at least on the surface. However, observing the organizational structures at the "Unit" level, it is found that "corporate planning" and "administration and finance" functions might not be sufficiently institutionalized. In other words out of the plan-do-see steps of corporate activities, "plan" and "see" steps must be better improved and reinforced.

CEAS is composed of 5 directorates, namely, Directorate of Studies and Projects, Directorate of Construction, Directorate of Treatment Plants, Directorate of

Operation and Directorate of Administration and Finance, and Internal Auditor. One observes that "corporate planning" functions are performed under Directorate of Studies and Projects, "new works" functions and activities are incorporated in Directorate of Construction, "water pollution control" functions are performed by Directorate of Treatment Plants, "sewerage operations and maintenance" activities are carried out under Directorate of Operation, and "administration and finance" functions are performed by Directorate of Administration and Finance, and Internal Auditor.

It appears that CEAS also satisfies all the requirements of a sewerage organization. Looking at the organizational structures at the "Department" level, it seems that "corporate planning" and "administration and finance" functions seem to be substantial. However, CEAS is financially in the red these years. It is hoped, therefore, that "plan" and "see" activities will be improved and reinforced more.

3.4 Alternatives of Sewerage Organization

The gigantic wastewater treatment plant the world has never seen in terms of wastewater treatment capacity is going to be constructed. The inescapable trends in the water sector in the world are the introduction of the principle of self-financing, the promotion of decentralization and the realization of efficiency.

It is the requirement of this age, therefore, that sewerage charge be introduced and implemented, the sewerage tariffs be so formulated as to recover the costs and the lethargy of a big organization be removed.

It appears that the opportunity has arrived for the sewerage portions of water organizations to be separated to form an independent organization. But, the realization of such an organization should be a gradual process.

JICA Study Team proposes that an independent sewerage organization be established in the course of time with the target year set at 2015. The recommended structure of the organization is shown in Fig. I.2. It is a skeleton structure meeting minimum requirements. The outlines of the functions/activities for the directorate level and in some cases for the sub-directorate level have been presented in a preceding section.

This organization will have the total workforce of around 2,500 in 2015. In 1997, the concluding year of the Urgent Project it will have the personnel of around 700.

This organization will make utmost efforts to resolve the institutional problems listed in section 3.1 and fulfill the financial self-support and stable management by 2015.

This organization will be a semi-governmental organization with a mixture of governmental control and profit pursuing management because of the social nature of the "business".

The sewerage service charge will be incorporated in the water supply charge bills for the sake of economy and efficiency. Cooperation with the water supply organizations is required in various fields for the same reason.

An independent sewerage organization has several advantages compared with an organization having both water supply and sewerage service functions. They are listed below:

1) An independent corporate targets can be established.

   The organization can pursue its own revenue and profit targets and the fruit of the efforts will have direct effects upon their remuneration.

2) Self-discipline mentality will be nurtured.

   The workers can no longer rely on the revenues from water supply. Now, they have to earn their own money. This situation will help nurture self-help and self-discipline mentality among them.

3) Lethargy and redundancy of a big organization will be reduced.

   In a big organization lethargy arising from the mentality of interdependence and self-complacency and organizational redundancy are likely to be witnessed. They will be reduced or removed. Thus, organizational revitalization and efficiency will be promoted.

4) Conflicts with water supply personnel will be removed.

   Conflicts between water supply and sewerage service personnel are not unusual in an organization with both functions. They will no longer suffer from them.

5) Technological improvement can be expected.

The functions of sewerage service tend to be placed behind those of water supply in an organization with both functions. It dampens the efforts toward technological improvement in sewerage service. Organizational independence will remove such an obstacle, promoting the atmosphere of technological development.

However, there are some disadvantages in the establishment of an independent sewerage organization.

There are many things that can be utilized and shared by both water supply and sewerage service personnel as shown below.

1) workforce
2) technology and know-how
3) equipment, vehicles and tools
4) facilities

This fact is a major reason behind the existence of the organization with both water supply and sewerage service functions. One has to part with such advantages in an independent sewerage organization. It leads to another alternative proposal that the existing organizations having both functions should continue to exist during and after the completion of the Project.

Under this proposal the sewerage service revenues deriving from the beneficiaries in the Federal District will belong to the Ministry of Federal District (DGCOH). Likewise, the sewerage service revenues deriving from the beneficiaries in the Mexico State will belong to the Government of Mexico State (CEAS, etc.).

Also, the Texcoco Wastewater Treatment Plant will be operated and managed by the Ministry of Federal District, but the costs concerned will be divided between the Ministry and the Government of Mexico State.

Table I.1 Important Values for Estimation of Economic Benefits

I. Related to Reduction of Water-Borne Diseases

1. Annual reduction of water-borne and water related disease cases per household: 1.1296 (1994)

Note: Agricultural household
Source: Sampling questionnaire survey conducted by JICA

2. Average medical cost per case : N$ 74.3

Source: Information and data from Servicios Coordinados de Salud Publica, Hidalgo State

3. Number of households in untreated sewage irrigated areas (1990)

Name of Area	Total Number Households	Number of Agricultural Households	Number of Non-Agricultural Households
Irrigation District of Tula	49,795	14,939	34,856
Irrigation District of Alfajayucan	24,423	11,598	12,825
Municipality of Ecatepec	238,117	1,096	237,021
Total	312,335	27,633	284,702

Sources: 1. Secretaria de Agricultura y Recursos Hidraulicos, Hidalgo State
2. Anuario Estadistico del Estado de Hidalgo
3. Anuario Estadistico del Estado de Mexico
4. JICA

II. Related to Increase of Agricultural Revenues

1. Average annual agricultural income per household and the difference in land productivity in untreated sewage irrigated and treated sewage irrigated areas

(Unit: N$)

Area	Average Annual Agricultural Income	Average Cultivated Area	Income per ha	Income per 4.90 ha
Untreated Sewage Irrigated Areas	10,225	4.90 ha	2,087	10,225
Treated Sewage Irrigated Areas	5,667	2.24 ha	2,530	12,397

Source: Sampling questionnaire surveys conducted by JICA

2. No. of agricultural households in untreated sewage irrigated areas
(See I. 3. in the above.)

Table I.2 Annual Incidence of Water-Borne and Water Related Diseases

(Unit : Cases / Household)

Name of Diseases	Untreated Sewage Irrigated Areas (A)	Treated Sewage Irrigated Areas (B)	Difference (A - B)
I. Water-Borne Diseases			
1. Malaria	0.0430	0.0208	0.0222
2. Diarrhoea	0.5054	0.0417	0.4637
3. Dysentery	0.0251	0.0000	0.0251
4. Cholera	0.0143	0.0000	0.0143
5. Typhoid	0.0466	0.0000	0.0466
6. Para-Typhoid	0.0036	0.0000	0.0036
7. Gastro-Enteritis	0.0251	0.0000	0.0251
8. Dengue Fever	0.0287	0.0000	0.0287
9. Tuberculosis	0.0072	0.0000	0.0072
10. Diphtheria	0.0072	0.0000	0.0072
11. Measles	0.0143	0.0130	0.0013
12. Hepatitis A/B	0.0036	0.0000	0.0036
Sub-Total	0.7241	0.0755	0.6486
II. Water Related Diseases			
1. Parasitic Diseases	0.3871	0.0781	0.3090
2. Skin Diseases	0.1720	0.0000	0.1720
Sub-Total	0.5591	0.0781	0.4810
Total	1.2832	0.1536	1.1296

Note: 1. Untreated sewage irrigated areas = Irrigation areas of Tula and Alfajayucan, Hidalgo State and Municipality of Ecatepec, Mexico State

2. Treated sewage irrigated areas = Delegations of Tlahuac and Xochimilco, Federal District

Source: Sampling questionnaire surveys conducted by JICA

Table I.3 Kinds of Cultivated Crops

1. Comparison of currently cultivated crops in untreated sewage irrigated and treated sewage irrigated areas

Untreated Sewage Irrigated Areas		Treated Sewage Irrigated Areas	
Name of Crops	Percentage of Multiple Answers	Name of Crops	Percentage of Multiple Answers
1. Maize	55.7	1. Lettuce	38.1
2. Alfalfa	29.8	2. Spinach	33.3
3. Tomato (Jitomate)	13.1	3. Flowers	18.0
4. Kidney Bean	9.8	4. Cauliflower	14.3
5. Lettuce	6.6	5. Carrot	12.7
6. Chayote	6.6	6. Cabbage	12.7
7. Chili	3.3	7. Coriander	11.1
8. Prickly Pear	3.3	8. Alfalfa	11.1
9. Onion	1.6	9. Broccoli	11.1
10. Carrot	1.6	10. Cucumber	9.5

2. Kinds of crops farmers in untreated sewage irrigated areas want to cultivate when sewage is treated

Name of Crops	Percentage of Multiple Answers
1. Lettuce	45.7
2. Pumpkin	33.3
3. Onion	25.9
4. Carrot	24.7
5. Beet	23.5
6. Tomato (Jitomate)	22.2
7. Chili	19.8
8. Potato	18.5
9. Tomato (Tomate)	14.8
10. Kidney Bean	11.1

Source: Sampling questionnaire surveys conducted by JICA

Table I.4 Calculation of Standard Conversion Factor

1. Imports/Exports

(Unit : N$ million)

Year	Imports	Exports
1989	65,482	56,237
1990	92,275	75,495
1991	120,549	81,848

Source : La Economia Mexicana en Cifras 1992 13a edicion, Nacional Franciera

2. Import/Export Duties and Taxes

(Unit : N$ million)

Year	Duties and Taxes	
	Imports	Exports
1989	3,755	90
1990	6,237	75
1991	9,760	35

Source : La Economia Mexicana en Cifras 1992 13a edicion, Nacional Franciera

3. Calculation of Standard Conversion Factor

1) Formula

$$SCF = (M + X) / ((M + tm) + (X - tx))$$

Where,
SCF : Standard conversion factor
M : Imports
X : Exports
tm : Import duties and taxes
tx : Export duties and taxes

2) Results

Year	SCF
1989	0.9710
1990	0.9646
1991	0.9542
Average	0.9633

Table I.5 Analysis of Water Price in the Study Area

I. Analysis of Current Water Price (1993)

1. Monthly water consumption per household

Area	Water Served	No. of Households Served	Monthly Water Consumption per Household
Federal District	779.3 Mm^3	1,703,119	38.1 m^3
Mexico State	323.3 Mm^3	908,814	29.6 m^3

Notes : Water includes commercial, institutional and industrial water.

2. Water price

Area	Monthly Domestic Water Consumption Per Household	Monthly Water Payment per Household	Domestic Water Price per m^3	Water Price per m^3
Federal District	26.0 m^3	20.85	N$ 0.802	N$ 1.056
Mexico State	20.5 m^3	17.92	N$ 0.874	N$ 1.142

II. Estimation of Water Price Fully Covering O & M Cost

1. Actual (1993)

Area	O&M Cost Budgeted/ Estimated (N$ Mln.)	Water Served (Mm^3)	Actual Collection Rate (%)	Water Price Covering O&M Cost (N$/$m^3$)	Domestic Water Price Covering O&M Cost (N$/$m^3$)
Federal District	1,217	779.3	60.0	2.603	1.976
Mexico State	240	323.3	59.6	1.246	0.953

2. for Planning

Area	O&M Cost Budgeted/ Estimated (N$ Mln.)	Water Served (Mm^3)	Planned Collection Rate (%)	Water Price Covering O&M Cost (N$/$m^3$)	Domestic Water Price Covering O&M Cost (N$/$m^3$)
Federal District	1,217	779.3	85	1.837	1.395
Mexico State	360	323.3	85	1.310	1.002

Sources: CNA, DGCOH, CEAS and sampling questionnaire surveys conducted by JICA

Table I.6 (1) Willingness to Pay for Water Supply and Sewerage Service

I. Monthly Amount a Household is Willing to Pay

1. For water supply

Legend : A = Results of questionnaire surveys
B = Values adopted for planning

Area	Monthly Amount a Household is Willing to Pay for Water Supply and Sewerage Svc.	Share of Payment for Water Supply		Monthly Amount a Household is Willing to Pay for Water Supply (for Planning)
		A	B	
Federal District	N$ 61	61.6%	60%	N$ 36.6
Mexico State	N$ 49	57.9%	60%	N$ 29.4

2. For sewerage service

Legend : A = Results of questionnaire surveys
B = Values adopted for planning

Area	Monthly Amount a Household is Willing to Pay for Water Supply and Sewerage Svc.	Share of Payment for Sewerage Svc.		Monthly Amount a Household is Willing to Pay for Sewerage Svc (for Planning)
		A	B	
Federal District	N$ 61	38.4%	40%	N$ 24.4
Mexico State	N$ 49	42.1%	40%	N$ 19.6

Table I.6 (2) Willingness to Pay for Water Supply and Sewerage Service

II. Water Supply and Sewerage Service Charge as Percentage of Household Income

1 Wilingness to pay

Area	Monthly Household Income	Willingness to Pay for Water Supply and Sewerage Svc. as Percentage of Household Income	Willingness to Pay for Water Supply as Percentage of Household Income	Willingness to Pay for Sewerage Service as Percentage of Household Income
Federal District	N$ 4,530	1.35%	0.81%	0.54%
Mexico State	N$ 2,421	2.02%	1.21%	0.81%

2. Current and planned domestic water supply charge

Area	Monthly Household Income	Current Monthly Domestic Water Supply Charge as Percentage of Household Income	Planned Monthly Domestic Water Supply Charge as Percentage of Household Income
Federal District	N$ 4,530	N$ 20.9/N$ 4,530=0.46%	N$36.3/N$4,530=0.80%
Mexico State	N$ 2,421	N$ 17.9/N$ 2,421=0.74%	N$20.5/N$2,421=0.85%

III. Willingness to Pay per m^3

1. For water supply

Area	Amount Households are Willing to Pay for Water Supply and Sewerage Svc. per m^3	Amount Households are Willing to Pay for Water Supply per m^3	Amount Beneficiaries are Willing to Pay for Water Supply per m^3
Federal District	N$ 2.392	N$ 1.435	N$ 1.890
Mexico State	N$ 2.390	N$ 1.434	N$ 1.874

2. For sewerage service

Area	Amount Households are Willing to Pay for Water Supply and Sewerage Svc. per m^3	Amount Households are Willing to Pay for Sewerage Service per m^3	Amount Beneficiaries are Willing to Pay for Sewerage Service per m^3
Federal District	N$ 2.392	N$ 0.957	N$ 1.260
Mexico State	N$ 2.390	N$ 0.956	N$ 1.249

Sources : Sampling questionnaire surveys conducted by JICA and other related sources

Table I.7(1) Financial Statement - Proposed Plan

(Unit: N$ million)

No.	1	2	3	4	5	6	7	8	9	10
Year	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Income Statement										
Revenue	0	0	0	338	342	346	350	355	359	363
Operation and Maintenance	0	0	0	84	84	84	84	84	84	84
Depreciation	0	24	49	49	49	49	49	49	49	49
Payment of Interest	0	0	0	84	79	75	70	64	57	52
Expenditure	0	24	49	216	212	207	202	197	190	184
Profit before Tax	0	-24	-49	122	131	139	149	158	169	179
Tax	0	0	0	61	65	70	74	79	85	89
Profit after Tax	0	-24	-49	61	65	70	74	79	85	89
Funds Statement										
Profit after Tax	0	-24	-49	61	65	70	74	79	85	89
Loans	142	626	625	0	0	0	0	0	0	0
Subsidies	0	0	0	0	0	0	0	0	0	0
Depreciation	0	24	49	49	49	49	49	49	49	49
Sources	142	626	625	110	114	118	123	127	133	138
Capital Works	142	626	625	0	0	0	0	0	0	0
Payment of Principal	0	0	0	82	86	91	95	100	106	111
Working Capital	0	0	0	28	28	28	28	27	28	27
Applications	142	626	625	110	114	118	123	127	133	138
Loan Liabilities	149	815	1,516	1,434	1,348	1,258	1,162	1,062	957	845
Cash Balance	0	0	0	28	56	84	111	138	166	193

Source: JICA

Table I.7(2) Financial Statement - Proposed Plan

(Unit: N$ million)

No.	11	12	13	14	15	16	17	18	19	20
Year	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Income Statement										
Revenue	367	371	375	379	383	388	392	396	400	404
Operation and Maintenance	84	84	84	84	98	113	127	142	157	171
Depreciation	49	49	49	63	78	89	100	112	123	134
Payment of Interest	46	39	33	26	18	11	3	0	0	0
Expenditure	178	172	165	173	194	212	231	254	280	306
Profit before Tax	189	199	210	207	189	175	160	142	120	99
Tax	94	100	105	103	95	88	80	71	60	49
Profit after Tax	94	100	105	103	95	88	80	71	60	49
Funds Statement										
Profit after Tax	94	100	105	103	95	88	80	71	60	49
Loans	0	0	16	422	437	322	322	337	322	322
Subsidies	0	0	0	0	0	0	0	0	0	0
Depreciation	49	49	49	63	78	89	100	112	123	134
Sources	143	148	170	588	609	498	502	520	505	505
Capital Works	0	0	16	422	437	322	426	441	322	322
Payment of Principal	117	123	130	136	143	132	64	0	0	0
Working Capital	26	25	24	30	29	44	12	78	183	184
Applications	143	148	170	588	609	498	502	520	505	505
Loan Liabilities	729	605	493	802	1,142	1,398	1,743	2,189	2,643	3,120
Cash Balance	219	244	268	299	327	372	384	462	645	829

Source: JICA

Table I.7(3) Financial Statement - Propsed Plan

(Unit: N$ million)

No.	21	22	23	24	25	26	27	28	29	30
Year	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Income Statement										
Revenue	408	653	653	653	653	653	653	653	653	653
Operation and Maintenance	186	200	200	200	200	200	200	200	200	200
Depreciation	146	146	146	146	146	146	146	146	146	146
Payment of Interest	0	202	185	167	148	128	104	83	60	43
Expenditure	331	548	531	513	494	474	450	429	406	389
Profit before Tax	77	105	122	140	159	179	203	225	247	264
Tax	38	53	61	70	80	89	102	112	123	132
Profit after Tax	38	53	61	70	80	89	102	112	123	132
Funds Statement										
Profit after Tax	38	53	61	70	80	89	102	112	123	132
Loans	322	0	0	0	0	0	0	0	0	0
Subsidies	0	0	0	0	0	0	0	0	0	0
Depreciation	146	146	146	146	146	146	146	146	146	146
Sources	506	198	207	216	225	235	247	258	269	278
Capital Works	322	0	0	0	0	0	0	0	21	21
Payment of Principal	0	307	323	340	358	376	396	412	323	242
Working Capital	184	-108	-116	-124	-132	-141	-149	-154	-75	15
Applications	506	198	207	216	225	235	247	258	269	278
Loan Liabilities	3,623	3,316	2,993	2,653	2,296	1,919	1,523	1,111	789	547
Cash Balance	1,013	904	788	664	532	390	241	88	13	28

Source: JICA

Table I.8(1) Financial Statement - Alternative I

(Unit: N$ million)

No.	1	2	3	4	5	6	7	8	9	10
Year	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Income Statement										
Revenue	0	0	0	225	228	231	234	236	239	242
Operation and Maintenance	0	0	0	84	84	84	84	84	84	84
Depreciation	0	24	49	49	49	49	49	49	49	49
Payment of Interest	0	0	0	0	0	6	34	66	92	116
Expenditure	0	24	49	132	132	139	166	199	224	249
Profit before Tax	0	-24	-49	93	96	92	68	38	15	-7
Tax	0	0	0	47	48	46	34	19	7	0
Profit after Tax	0	-24	-49	47	48	46	34	19	7	-7
Funds Statement										
Profit after Tax	0	-24	-49	47	48	46	34	19	7	-7
Loans	142	626	625	0	0	0	0	0	0	0
Subsidies	0	0	0	0	0	0	0	0	0	0
Depreciation	0	24	49	49	49	49	49	49	49	49
Sources	142	626	625	95	96	95	82	67	56	42
Capital Works	142	626	625	0	0	0	0	0	0	0
Payment of Principal	0	0	0	0	0	3	17	36	58	80
Working Capital	0	0	0	95	96	92	65	31	-2	-38
Applications	142	626	625	95	96	95	82	67	56	42
Loan Liabilities	150	822	1,533	1,625	1,722	1,817	1,877	1,889	1,856	1,776
Cash Balance	0	0	0	95	192	283	348	379	378	339

Source: JICA

Table I.8(2) Financial Statement - Alternative I

(Unit: N$ million)

No.	11	12	13	14	15	16	17	18	19	20
Year	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Income Statement										
Revenue	245	247	250	443	447	452	457	462	467	471
Operation and Maintenance	84	84	84	84	98	113	127	142	157	171
Depreciation	49	49	49	63	78	89	100	112	123	134
Payment of Interest	111	105	99	92	85	78	70	63	74	84
Expenditure	243	237	231	239	260	280	298	317	353	390
Profit before Tax	1	10	19	204	187	173	159	145	113	82
Tax	1	5	10	102	93	86	79	72	57	41
Profit after Tax	1	5	10	102	93	86	79	72	57	41
Funds Statement										
Profit after Tax	1	5	10	102	93	86	79	72	57	41
Loans	0	0	16	422	437	322	322	337	322	322
Subsidies	0	0	0	0	0	0	0	0	0	0
Depreciation	49	49	49	63	78	89	100	112	123	134
Sources	49	54	74	587	608	497	501	521	501	497
Capital Works	0	0	16	422	437	322	426	441	322	322
Payment of Principal	85	90	96	102	108	115	122	130	147	167
Working Capital	-36	-37	-38	63	63	60	-47	-50	32	8
Applications	49	54	74	587	608	497	501	521	501	497
Loan Liabilities	1,691	1,601	1,522	1,868	2,250	2,534	2,834	3,167	3,476	3,775
Cash Balance	303	266	229	292	355	415	368	318	350	359

Source: JICA

Table I.8(3) Financial Statement - Alternative I

(Unit: N$ million)

No.	21	22	23	24	25	26	27	28	29	30
Year	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Income Statement										
Revenue	476	612	612	612	612	612	612	612	612	612
Operation and Maintenance	186	200	200	200	200	200	200	200	200	200
Depreciation	146	146	146	146	146	146	146	146	146	146
Payment of Interest	107	128	146	165	183	197	196	197	183	169
Expenditure	438	474	493	511	529	543	542	543	529	515
Profit before Tax	38	138	120	101	84	69	70	70	83	97
Tax	19	69	60	51	42	35	35	35	41	48
Profit after Tax	19	69	60	51	42	35	35	35	41	48
Funds Statement										
Profit after Tax	19	69	60	51	42	35	35	35	41	48
Loans	322	0	0	0	0	0	0	0	0	0
Subsidies	0	0	0	0	0	0	0	0	0	0
Depreciation	146	146	146	146	146	146	146	146	146	146
Sources	487	215	206	196	188	180	181	180	187	194
Capital Works	322	0	0	0	0	0	0	0	21	21
Payment of Principal	188	180	167	194	222	241	220	197	210	222
Working Capital	-23	35	38	3	-34	-61	-39	-17	-43	-49
Applications	487	215	206	196	188	180	181	180	187	194
Loan Liabilities	4,048	3,984	3,912	3,791	3,619	3,403	3,196	2,999	2,789	2,567
Cash Balance	336	371	409	411	377	316	277	260	216	167

Source: JICA

Table I.9(1) Financial Statement - Alternative II

(Unit: N$ million)

No.	1	2	3	4	5	6	7	8	9	10
Year	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Income Statement										
Revenue	0	0	0	282	285	289	292	295	299	302
Operation and Maintenance	0	0	0	84	84	84	84	84	84	84
Depreciation	0	24	49	49	49	49	49	49	49	49
Payment of Interest	0	0	0	0	0	16	84	150	144	137
Expenditure	0	24	49	132	132	148	217	282	276	270
Profit before Tax	0	-24	-49	149	153	141	76	13	23	33
Tax	0	0	0	75	76	70	38	7	11	16
Profit after Tax	0	-24	-49	75	76	70	38	7	11	16
Funds Statement										
Profit after Tax	0	-24	-49	75	76	70	38	7	11	16
Loans	142	626	625	0	0	0	0	0	0	0
Subsidies	0	0	0	0	0	0	0	0	0	0
Depreciation	0	24	49	49	49	49	49	49	49	49
Sources	142	626	625	123	125	119	86	55	60	65
Capital Works	142	626	625	0	0	0	0	0	0	0
Payment of Principal	0	0	0	0	0	8	43	81	86	93
Working Capital	0	0	0	123	125	111	43	-25	-27	-28
Applications	142	626	625	123	125	119	86	55	60	65
Loan Liabilities	152	835	1,568	1,684	1,809	1,920	1,939	1,858	1,772	1,679
Cash Balance	0	0	0	123	248	359	403	377	351	323

Source: JICA

Table I.9(2) Financial Statement - Alternative II

(Unit: N$ million)

No.	11	12	13	14	15	16	17	18	19	20
Year	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Income Statement										
Revenue	306	309	313	443	447	452	457	462	467	471
Operation and Maintenance	84	84	84	84	98	113	127	142	157	171
Depreciation	49	49	49	63	78	89	100	112	123	134
Payment of Interest	130	121	112	103	94	84	73	63	97	130
Expenditure	262	253	244	250	270	285	301	317	377	436
Profit before Tax	44	56	69	193	178	167	156	145	90	36
Tax	22	28	34	96	89	83	78	73	45	18
Profit after Tax	22	28	34	96	89	83	78	73	45	18
Funds Statement										
Profit after Tax	22	28	34	96	89	83	78	73	45	18
Loans	0	0	16	422	437	322	322	337	322	322
Subsidies	0	0	0	0	0	0	0	0	0	0
Depreciation	49	49	49	63	78	89	100	112	123	134
Sources	70	76	99	581	603	494	500	521	490	474
Capital Works	0	0	16	422	437	322	426	441	322	322
Payment of Principal	100	107	115	124	133	143	153	165	201	240
Working Capital	-29	-31	-32	36	34	30	-79	-86	-33	-88
Applications	70	76	99	581	603	494	500	521	490	474
Loan Liabilities	1,579	1,472	1,374	1,705	2,076	2,352	2,647	2,978	3,250	3,471
Cash Balance	293	263	231	267	300	330	251	166	133	45

Source: JICA

Table I.9(3) Financial Statement - Alternative II

(Unit: N$ million)

No.	21	22	23	24	25	26	27	28	29	30
Year	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Income Statement										
Revenue	476	680	680	680	680	680	680	680	680	680
Operation and Maintenance	186	200	200	200	200	200	200	200	200	200
Depreciation	146	146	146	146	146	146	146	146	146	146
Payment of Interest	148	164	187	212	236	257	241	224	205	185
Expenditure	479	510	533	558	582	603	587	570	551	531
Profit before Tax	-3	170	148	122	98	77	93	111	129	149
Tax	0	85	74	61	49	38	47	55	65	75
Profit after Tax	-3	85	74	61	49	38	47	55	65	75
Funds Statement										
Profit after Tax	-3	85	74	61	49	38	47	55	65	75
Loans	322	0	0	0	0	0	0	0	0	0
Subsidies	0	0	0	0	0	0	0	0	0	0
Depreciation	146	146	146	146	146	146	146	146	146	146
Sources	465	231	219	207	195	184	192	201	210	220
Capital Works	322	0	0	0	0	0	0	0	21	21
Payment of Principal	252	188	120	147	175	206	221	238	255	274
Working Capital	-109	43	99	60	19	-22	-29	-37	-66	-75
Applications	465	231	219	207	195	184	192	201	210	220
Loan Liabilities	3,680	3,608	3,576	3,491	3,347	3,141	2,920	2,682	2,427	2,152
Cash Balance	-64	-22	78	137	157	135	106	69	3	-72

Source: JICA

Table I.10(1) Financial Statement - Alternative III

(Unit: N$ million)

No.	1	2	3	4	5	6	7	8	9	10
Year	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Income Statement										
Revenue	0	0	0	338	342	346	350	355	359	363
Operation and Maintenance	0	0	0	84	84	84	84	84	84	84
Depreciation	0	24	49	49	49	49	49	49	49	49
Payment of Interest	0	0	0	13	71	126	119	111	102	92
Expenditure	0	24	49	146	204	258	251	243	234	224
Profit before Tax	0	-24	-49	192	139	88	100	112	125	139
Tax	0	0	0	96	69	44	50	56	62	69
Profit after Tax	0	-24	-49	96	69	44	50	56	62	69
Funds Statement										
Profit after Tax	0	-24	-49	96	69	44	50	56	62	69
Loans	142	626	625	0	0	0	0	0	0	0
Subsidies	0	0	0	0	0	0	0	0	0	0
Depreciation	0	24	49	49	49	49	49	49	49	49
Sources	142	626	625	145	118	93	98	104	111	118
Capital Works	142	626	625	0	0	0	0	0	0	0
Payment of Principal	0	0	0	10	53	99	106	114	122	131
Working Capital	0	0	0	135	65	-6	-8	-10	-11	-13
Applications	142	626	625	145	118	93	98	104	111	118
Loan Liabilities	152	834	1,566	1,658	1,657	1,558	1,452	1,338	1,216	1,085
Cash Balance	0	0	0	135	200	194	186	176	165	152

Source: JICA

Table I.10(2) Financial Statement - Alternative III

(Unit: N$ million)

No.	11	12	13	14	15	16	17	18	19	20
Year	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Income Statement										
Revenue	367	371	375	443	447	452	457	462	467	471
Operation and Maintenance	84	84	84	84	98	113	127	142	157	171
Depreciation	49	49	49	63	78	89	100	112	123	134
Payment of Interest	81	71	59	47	34	22	48	80	105	129
Expenditure	213	203	192	194	210	224	276	334	385	435
Profit before Tax	154	168	184	249	237	229	181	128	82	37
Tax	77	84	92	124	119	114	91	64	41	18
Profit after Tax	77	84	92	124	119	114	91	64	41	18
Funds Statement										
Profit after Tax	77	84	92	124	119	114	91	64	41	18
Loans	0	0	16	422	437	322	322	337	322	322
Subsidies	0	0	0	0	0	0	0	0	0	0
Depreciation	49	49	49	63	78	89	100	112	123	134
Sources	125	133	157	609	633	525	513	513	486	475
Capital Works	0	0	16	422	437	322	426	441	322	322
Payment of Principal	141	151	162	174	187	179	122	62	88	116
Working Capital	-15	-18	-22	13	10	24	-35	10	76	37
Applications	125	133	157	609	633	525	513	513	486	475
Loan Liabilities	944	793	648	928	1,244	1,480	1,766	2,118	2,428	2,711
Cash Balance	136	118	96	109	119	143	108	117	193	230

Source: JICA

Table I.10(3) Financial Statement - Alternative III

(Unit: N$ million)

No.	21	22	23	24	25	26	27	28	29	30
Year	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Income Statement										
Revenue	476	680	680	680	680	680	680	680	680	680
Operation and Maintenance	186	200	200	200	200	200	200	200	200	200
Depreciation	146	146	146	146	146	146	146	146	146	146
Payment of Interest	152	170	187	200	181	160	138	114	89	67
Expenditure	483	516	533	546	527	506	484	460	435	413
Profit before Tax	-7	164	148	134	154	174	197	220	246	267
Tax	0	82	74	67	77	87	98	110	123	134
Profit after Tax	-7	82	74	67	77	87	98	110	123	134
Funds Statement										
Profit after Tax	-7	82	74	67	77	87	98	110	123	134
Loans	322	0	0	0	0	0	0	0	0	0
Subsidies	0	0	0	0	0	0	0	0	0	0
Depreciation	146	146	146	146	146	146	146	146	146	146
Sources	460	228	220	213	222	233	244	256	268	279
Capital Works	322	0	0	0	0	0	0	0	21	21
Payment of Principal	148	180	215	253	271	291	312	332	290	242
Working Capital	-9	47	4	-40	-49	-58	-68	-77	-42	16
Applications	460	228	220	213	222	233	244	256	268	279
Loan Liabilities	2,961	2,833	2,645	2,393	2,121	1,831	1,518	1,186	896	654
Cash Balance	221	268	273	233	184	126	57	-19	-62	-45

Source: JICA

Table I.11 Cost Benefit Streams - Proposed Plan

CC=Capital Costs; OM=O/M Costs; CS=Costs; BF=Benefits
CF=Cash Flow (=BF - CS)

(Unit:N$ Million)

NO.	YEAR	CC	OM	CS	BF	CF
1	1995	142	0	142	0	-142
2	1996	626	0	626	0	-626
3	1997	625	0	625	0	-625
4	1998	0	84	84	338	254
5	1999	0	84	84	342	258
6	2000	0	84	84	346	263
7	2001	0	84	84	350	267
8	2002	0	84	84	355	271
9	2003	0	84	84	359	275
10	2004	0	84	84	363	279
11	2005	0	84	84	367	283
12	2006	0	84	84	371	287
13	2007	16	84	100	375	275
14	2008	422	84	506	379	-126
15	2009	437	98	535	383	-151
16	2010	322	113	435	388	-47
17	2011	426	127	554	392	-162
18	2012	441	142	583	396	-188
19	2013	322	157	478	400	-78
20	2014	322	171	493	404	-89
21	2015	322	186	508	408	-100
22	2016	0	200	200	653	453
23	2017	0	200	200	653	453
24	2018	0	200	200	653	453
25	2019	0	200	200	653	453
26	2020	0	200	200	653	453
27	2021	0	200	200	653	453
28	2022	0	200	200	653	453
29	2023	21	200	221	653	432
30	2024	21	200	221	653	432

Table I.12 Cost Benefit Streams - Alternative I

CC=Capital Costs; OM=O/M Costs; CS=Costs; BF=Benefits
CF=Cash Flow (=BF - CS)

(Unit:N$ Million)

NO.	YEAR	CC	OM	CS	BF	CF
1	1995	142	0	142	0	-142
2	1996	626	0	626	0	-626
3	1997	625	0	625	0	-625
4	1998	0	84	84	225	142
5	1999	0	84	84	228	144
6	2000	0	84	84	231	147
7	2001	0	84	84	234	150
8	2002	0	84	84	236	153
9	2003	0	84	84	239	155
10	2004	0	84	84	242	158
11	2005	0	84	84	245	161
12	2006	0	84	84	247	164
13	2007	16	84	100	250	150
14	2008	422	84	506	443	-63
15	2009	437	98	535	447	-88
16	2010	322	113	435	452	17
17	2011	426	127	554	457	-97
18	2012	441	142	583	462	-122
19	2013	322	157	478	467	-12
20	2014	322	171	493	471	-22
21	2015	322	186	508	476	-31
22	2016	0	200	200	612	412
23	2017	0	200	200	612	412
24	2018	0	200	200	612	412
25	2019	0	200	200	612	412
26	2020	0	200	200	612	412
27	2021	0	200	200	612	412
28	2022	0	200	200	612	412
29	2023	21	200	221	612	391
30	2024	21	200	221	612	391

Table I.13 Cost Benefit Streams - Alternative II

CC=Capital Costs; OM=O/M Costs; CS=Costs; BF=Benefits
CF=Cash Flow (=BF - CS)

(Unit:N$ Million)

NO.	YEAR	CC	OM	CS	BF	CF
1	1995	142	0	142	0	-142
2	1996	626	0	626	0	-626
3	1997	625	0	625	0	-625
4	1998	0	84	84	282	198
5	1999	0	84	84	285	201
6	2000	0	84	84	289	205
7	2001	0	84	84	292	208
8	2002	0	84	84	295	212
9	2003	0	84	84	299	215
10	2004	0	84	84	302	219
11	2005	0	84	84	306	222
12	2006	0	84	84	309	226
13	2007	16	84	100	313	213
14	2008	422	84	506	443	-63
15	2009	437	98	535	447	-88
16	2010	322	113	435	452	17
17	2011	426	127	554	457	-97
18	2012	441	142	583	462	-122
19	2013	322	157	478	467	-12
20	2014	322	171	493	471	-22
21	2015	322	186	508	476	-31
22	2016	0	200	200	680	480
23	2017	0	200	200	680	480
24	2018	0	200	200	680	480
25	2019	0	200	200	680	480
26	2020	0	200	200	680	480
27	2021	0	200	200	680	480
28	2022	0	200	200	680	480
29	2023	21	200	221	680	459
30	2024	21	200	221	680	459

Table I.14 Cost Benefit Streams - Alternative III

CC=Capital Costs; OM=O/M Costs; CS=Costs; BF=Benefits
CF=Cash Flow (=BF - CS)

(Unit:N$ Million)

NO.	YEAR	CC	OM	CS	BF	CF
1	1995	142	0	142	0	-142
2	1996	626	0	626	0	-626
3	1997	625	0	625	0	-625
4	1998	0	84	84	338	254
5	1999	0	84	84	342	258
6	2000	0	84	84	346	263
7	2001	0	84	84	350	267
8	2002	0	84	84	355	271
9	2003	0	84	84	359	275
10	2004	0	84	84	363	279
11	2005	0	84	84	367	283
12	2006	0	84	84	371	287
13	2007	16	84	100	375	275
14	2008	422	84	506	443	-63
15	2009	437	98	535	447	-88
16	2010	322	113	435	452	17
17	2011	426	127	554	457	-97
18	2012	441	142	583	462	-122
19	2013	322	157	478	467	-12
20	2014	322	171	493	471	-22
21	2015	322	186	508	476	-31
22	2016	0	200	200	680	480
23	2017	0	200	200	680	480
24	2018	0	200	200	680	480
25	2019	0	200	200	680	480
26	2020	0	200	200	680	480
27	2021	0	200	200	680	480
28	2022	0	200	200	680	480
29	2023	21	200	221	680	459
30	2024	21	200	221	680	459

Table I.15(1) Financial Statement - Proposed Plan (Urgent Project)

(Unit: N$ million)

No.	1	2	3	4	5	6	7	8	9	10
Year	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Income Statement										
Revenue	0	0	0	237	240	242	245	248	251	254
Operation and Maintenance	0	0	0	84	84	84	84	84	84	84
Depreciation	0	24	49	49	49	49	49	49	49	49
Payment of Interest	0	0	0	84	79	75	70	64	57	52
Expenditure	0	24	49	216	212	207	202	197	190	184
Profit before Tax	0	-24	-49	21	28	36	43	52	61	70
Tax	0	0	0	10	14	18	22	26	31	35
Profit after Tax	0	-24	-49	10	14	18	22	26	31	35
Funds Statement										
Profit after Tax	0	-24	-49	10	14	18	22	26	31	35
Loans	142	626	625	0	0	0	0	0	0	0
Subsidies	0	0	0	0	0	0	0	0	0	0
Depreciation	0	24	49	49	49	49	49	49	49	49
Sources	142	626	625	59	63	66	70	74	79	84
Capital Works	142	626	625	0	0	0	0	0	0	0
Payment of Principal	0	0	0	82	86	91	95	100	106	111
Working Capital	0	0	0	-23	-23	-24	-25	-26	-26	-27
Applications	142	626	625	59	63	66	70	74	79	84
Loan Liabilities	149	815	1,516	1,434	1,348	1,258	1,162	1,062	957	845

Source: JICA

Table I.15(2) Financial Statement - Proposed Plan (Urgent Project)

(Unit: N$ million)

No.	11	12	13	14	15	16	17	18	19	20
Year	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Income Statement										
Revenue	257	260	263	266	268	271	274	277	280	283
Operation and Maintenance	84	84	84	84	84	84	84	84	84	84
Depreciation	49	49	49	49	49	49	49	49	49	49
Payment of Interest	46	39	33	26	18	11	3	0	0	0
Expenditure	178	172	165	158	151	143	136	132	132	132
Profit before Tax	79	88	98	108	118	128	138	145	148	151
Tax	39	44	49	54	59	64	69	72	74	75
Profit after Tax	39	44	49	54	59	64	69	72	74	75
Funds Statement										
Profit after Tax	39	44	49	54	59	64	69	72	74	75
Loans	0	0	0	0	0	0	0	0	0	0
Subsidies	0	0	0	0	0	0	0	0	0	0
Depreciation	49	49	49	49	49	49	49	49	49	49
Sources	88	93	97	102	107	113	118	121	122	124
Capital Works	0	0	0	0	0	0	104	104	0	0
Payment of Principal	117	123	130	136	143	132	64	0	0	0
Working Capital	-29	-30	-32	-34	-36	-19	-51	17	122	124
Applications	88	93	97	102	107	113	118	121	122	124
Loan Liabilities	729	605	476	340	196	64	0	0	0	0

Source: JICA

Table I.15(3) Financial Statement - Proposed PLan (Urgent Project)

(Unit: N$ million)

No.	21	22	23	24	25	26	27	28	29	30
Year	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Income Statement										
Revenue	286	286	286	286	286	286	286	286	286	286
Operation and Maintenance	84	84	84	84	84	84	84	84	84	84
Depreciation	49	49	49	49	49	49	49	49	49	49
Payment of Interest	0	0	0	0	0	0	0	0	0	0
Expenditure	132	132	132	132	132	132	132	132	132	132
Profit before Tax	153	153	153	153	153	153	153	153	153	153
Tax	77	77	77	77	77	77	77	77	77	77
Profit after Tax	77	77	77	77	77	77	77	77	77	77
Funds Statement										
Profit after Tax	77	77	77	77	77	77	77	77	77	77
Loans	0	0	0	0	0	0	0	0	0	0
Subsidies	0	0	0	0	0	0	0	0	0	0
Depreciation	49	49	49	49	49	49	49	49	49	49
Sources	125	125	125	125	125	125	125	125	125	125
Capital Works	0	0	0	0	0	0	0	0	0	0
Payment of Principal	0	0	0	0	0	0	0	0	0	0
Working Capital	125	125	125	125	125	125	125	125	125	125
Applications	125	125	125	125	125	125	125	125	125	125
Loan Liabilities	0	0	0	0	0	0	0	0	0	0

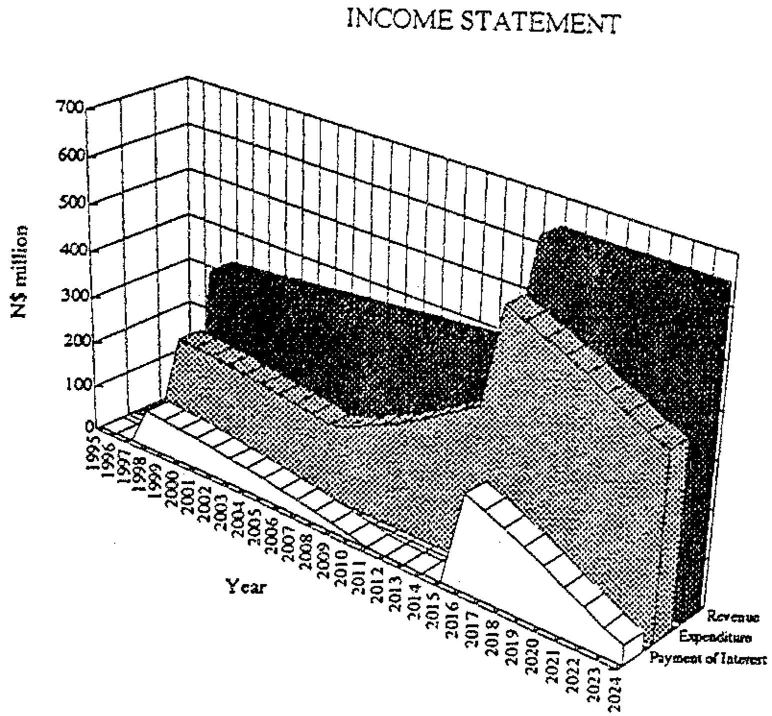
Source: JICA

Table I.16 Cost Benefit Streams - Proposed Plan (Urgent Project)

CC=Capital Costs; OM=O/M Costs; CS=Costs; BF=Benefits
CF=Cash Flow (=BF - CS)

(Unit:N$ Million)

NO.	YEAR	CC	OM	CS	BF	CF
1	1995	170	0	170	0	-170
2	1996	751	0	751	0	-751
3	1997	750	0	750	0	-750
4	1998	0	84	84	237	153
5	1999	0	84	84	240	156
6	2000	0	84	84	242	159
7	2001	0	84	84	245	162
8	2002	0	84	84	248	164
9	2003	0	84	84	251	167
10	2004	0	84	84	254	170
11	2005	0	84	84	257	173
12	2006	0	84	84	260	176
13	2007	0	84	84	263	179
14	2008	0	84	84	266	182
15	2009	0	84	84	268	185
16	2010	0	84	84	271	188
17	2011	125	84	209	274	65
18	2012	125	84	209	277	68
19	2013	0	84	84	280	196
20	2014	0	84	84	283	199
21	2015	0	84	84	286	202
22	2016	0	84	84	286	202
23	2017	0	84	84	286	202
24	2018	0	84	84	286	202
25	2019	0	84	84	286	202
26	2020	0	84	84	286	202
27	2021	0	84	84	286	202
28	2022	0	84	84	286	202
29	2023	0	84	84	286	202
30	2024	0	84	84	286	202



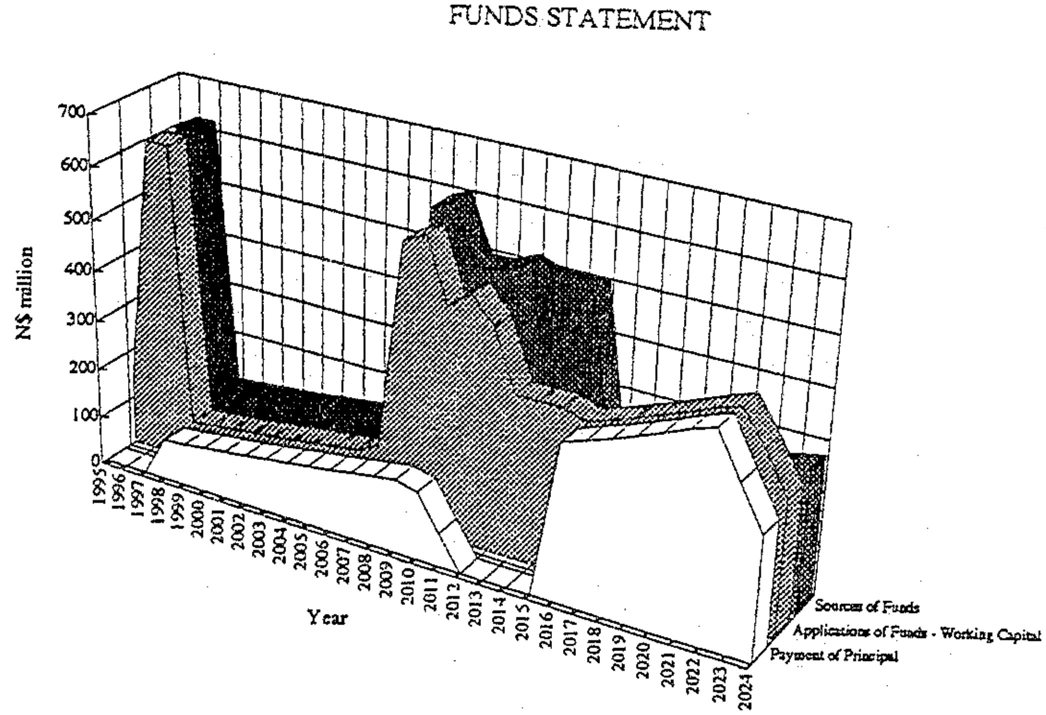


Fig. I.1 Financial Statement - Proposed Plan

THE FEASIBILITY STUDY ON WASTEWATER TREATMENT IN THE FEDERAL DISTRICT OF MEXICO

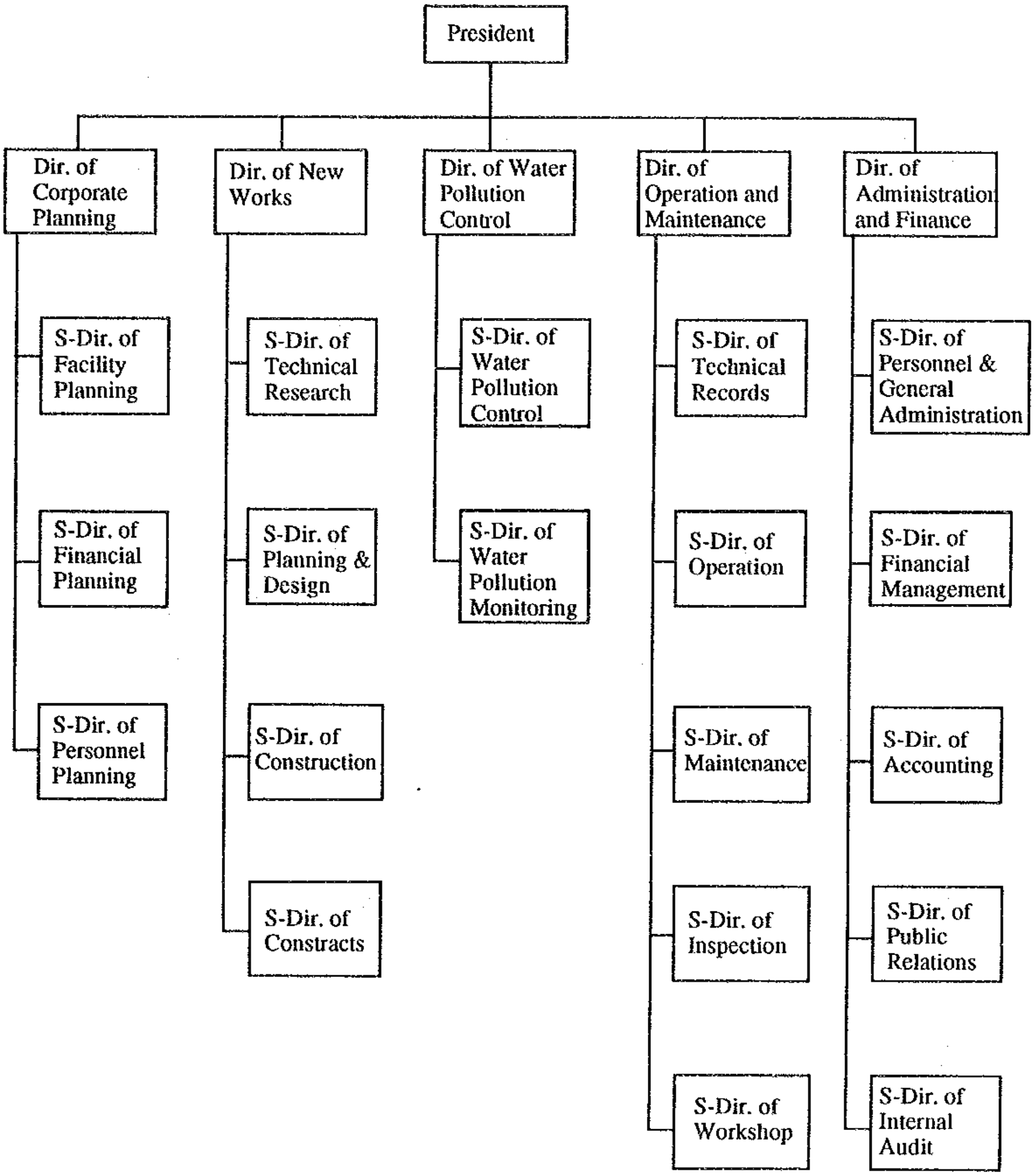


Fig. I.2 Proposed Structure of Sewerage Organization

APPENDIX J

APPENDIX J SUPPLEMENTARY REPORT

1. Wastewater Reuse

The increasing population coupled with scarcity of water resources in the study area has led to the over exploitation of the aquifers in the Mexico Valley and consequently problems such as pollution of aquifers and sinking of Mexico city have been observed. The perspectives of developing new water resources are less encouraging and hence treated wastewater has been considered as the possible alternative water resource. All the existing treatment plants have been constructed with the objective of reusing treated wastewater.

This guideline manual presents broadly the various categories of treated wastewater reuse, water quality requirements for the various reuses, problems associated with the respective reuses and possible remedies for the problems.

1.1 Categories of Wastewater Reuse

Wastewater reuse has been categorized into seven categories;

1) Agricultural Irrigation

Agricultural Irrigation has constituted more than 50% of all reuse activities. Within the agricultural reuse category irrigation with treated water may be utilized for the following:

a. Food crops
b. Fodder, fiber and seed crops
c. Pasture for milking animals

2) Landscape Irrigation

Urban irrigation of landscaped areas using treated water represents the fastest growing reuse option. Because residential and commercial landscape watering comprise more than 40% of the total water consumption in arid and semi-arid regions, substitution of treated water for potable water in a dual distribution system can generate significant long term benefits to a community's water supply sources. Based on the potential for public exposure to reuse activities, treated water irrigation of landscaped irrigation can be divided into the following sub categories.

a. Golf course, cementery, freeway medium and green belt irrigation
b. Parks, playground and school yard irrigation

3) Industrial Recycling and Reuse

Treated municipal wastewater has been utilized by industry for the following:

a. Cooling water
b. Process water
c. Boiler feed water

Treated water used as cooling water constitutes 99% of the total volume of industrial reuse water. The use of recycled wastewater for cooling water is common because of the lack of stringent water quality requirements and the relative ease of implementation. Industries with potential process water reuse requirements include primary metal production, petroleum and coal products, tanning, lumber, textiles chemicals, pulp and paper, food canning and soft drinks. Although the use of treated water for boiler feed water is technically feasible, it has proven to be operationally difficult to achieve because of severe problems with scaling.

4) Recreational and Environmental Uses

This category of water reuse serve typically as an aesthetic feature. Depending upon public access limitations or use restrictions, thus category can be further classified into two sub-headings:

a. Restricted recreational use; recreation limited to fishing, boating and other non-body contact water recreation activities

b. Nonrestricted recreational use; no limitation imposed on body contact water sport activities

5) Groundwater Recharge

The use of reclaimed water for groundwater recharge and the control of salt water intrusion may be accomplished through either of the following:

a. Injection wells
b. Surface spreading

Recharge which represents an indirect potable water reuse option is employed to: reduce, stop or reverse declines in groundwater levels due to aquifer overdrafting; provide a means to store treated effluent for future beneficial purposes; and, protect underground freshwater in coastal aquifers against salt water intrusion.

6) Non potable Urban Uses

Non potable urban uses can be further classified into following:

a. Toilet flushing
b. Vehicle washing
c. Road sprinkling

7) Potable Reuses

In extreme cases, drinking water is obtained from wastewater. However this reuse category require advanced treatment of wastewater and also biggest hurdle could be the public acceptance.

Among these reuses, agricultural irrigation, landscape irrigation, industrial reuse and recreational reuses can be considered as conventional reuses and groundwater recharging, non potable reuses and potable reuses can be considered as non conventional reuses. At present conventional reuses are being practiced in some areas of D.F. Mexico and groundwater recharging is being practiced on experimental basis.

1.2 Water Quality Criteria for Various Reuses

1.2.1 Agricultural and Landscape Irrigation

A) Physical and Chemical Water Quality

The physical and chemical water quality is of particular importance in arid zones where extremes of temperature and low humidity result in high rate of evapotranspiration. Table J.1 shows the guidelines for interpretations of water quality for irrigation and Table J.2 shows the suggested maximum limit of trace elements for irrigation waters.

B) Health and Regulatory Requirements

The biggest concern with the use of wastewater for irrigation is that untreated or inadequately treated wastewater contains numerous enteric helminths such as hookworm, ascaris, trichuris, and, under certain circumstances, the beef tapeworm. These infectious agents as well as other microbiological pathogens, can damage the health of the general public consuming the contaminated crops and can also harm farm workers and their families.

WHO has recommended the various requirements for the treated water to be used for irrigation as well as for other uses. Fig. J.1 shows the WHO guidelines for treatment processes to meet the given health criteria for wastewater reuse.

1.2.2 Industrial Reuse

Fig J.1 shows the WHO guidelines for the quality of treated water for industrial purpose also. The major parameters of concern and their concentrations for cooling water is described in Table J.3.

1.2.3 Groundwater Recharge

The level of municipal wastewater treatment necessary to produce a suitable reclaimed wastewater for groundwater recharge depends upon the groundwater quality objectives, hydrogeologic characteristics of the groundwater basin and the amount of reclaimed wastewater recharged in relation to other waters recharged. Factors to be considered in the formulation of the groundwater recharge guidelines are summarized in Table J.4.

1.2.4 Potable Reuse

Table J.5 shows the quality of treated water required for producing potable water.

1.3 Problems Associated with the Respective Reuse

1.3.1 Agriculture Irrigation and Landscape Irrigation

A) Salinity Problem

Salinity causes osmotic effects, soil particle dispersion and toxicity. Salts tend to concentrate in the root zone owing to evapotranspiration and plant damage is tied closely to an increase in soil salinity.

B) Specific Ion Toxicity on Plant Growth

The ions of most concern are Na, Cl and Boron. Boron is present in household detergents and discharges from industrial effluents. Na and Cl are present specially when water softener is used.

The study area has problem of high boron concentration due to soil characteristics and hence proper care should be taken which is described in subsequent section.

C) Water Infiltration Rate

Another indirect effect of high Na content is the deterioration of the physical concentration of a soil (formation of crusts, water clogging, reduced soil permeability)

SAR = Sodium Adsorption Ratio

$$= \frac{Na}{(Ca + Mg)^{0.5}}$$

For a given SAR, Infiltration rate increases as salinity increases and Infiltration rate decreases as salinity decreases. Hence SAR should be used in combination with Electrical conductivity to evaluate potential permeability problem.

D) Miscellaneous Problems

The problem of clogging with sprinkler and drip irrigation system is observed. And if Cl residual is in excess of 5 mg/l, it can cause severe plant damage, when reclaimed wastewater is sprayed directly on the foliage.

1.3.2 Industrial Reuse

Cooling tower make up water represents a significant water use for many industries, hence common water quality problems associated with cooling tower system are described below.

A) Scaling

Scaling refers to the formation of hard deposits, usually on hot surfaces, which reduce the efficiency of heat exchange. Calcium Scales ($CaCO_3$, $CaSO_4$ and $Ca_3(PO_4)_2$) are the principal causes of cooling tower scaling problems. Magnesium Scales ($MgCO_3$, $Mg_3(PO_4)_2$) and Silica deposits can also be a problem.

B) Metallic Corrosion

Total Dissolved Solids increase the electrical conductivity of the solution and accelerate corrosion reaction. DO and certain metals promote corrosion because of their relatively high oxidation potential.

C) Biological Growth

If attach and deposit on heat exchanger surfaces, inhibit heat transfer and water flow. Biological growth may also settle and bind other debris present in the cooling water, which may further inhibit effective heat transfer.

D) Fouling

The process of attachment and growth of deposits of various kinds in cooling tower recirculation systems is known as Fouling. These deposits consist of biological growths, SS, silt, corrosion products and inorganic scales. Fouling could lead to inhibition of heat transfer in the heat exchangers.

1.3.3 Groundwater Recharge

The major concern with groundwater recharge with reclaimed wastewater is that potentially adverse health effects may be caused by the introduction of pathogens or trace amounts of toxic contaminants. Because of the increasing concern for long-term health effects, every effort should be made to reduce the number of chemical species and the concentration of specific organic constituents in the recharge water.

1.3.4 Recreational and Environmental Reuses

The major concern is the health concerns of bacteria and viruses. Also eutrophication due to nitrogen and phosphorous present in receiving water causes problem. Toxicity to aquatic life could be another problem in recreational and environmental reuses.

1.3.5 Non Potable Urban Uses

In case of toilet flushing, fear of cross connection between treated water and potable water is the major problem.

1.3.6 Potable Reuses

Constituents specially, trace organic chemicals present in treated water causes problem due to their toxicological effects. Health concerns about pathogen transmission, particularly viruses is another important problem. Aesthetics and public acceptance is one of the major hindrance in using treated water for potable purposes.

1.4 Possible Measures to Avoid Problem of Treated Wastewater Reuse

1.4.1 Agricultural and Landscape Irrigation

As described in the previous section, salinity and specific ion toxicity is the major problem associated with the treated water reuse for irrigation. Water quality requirements and maximum permissible limits of various ions have been described. Besides following those requirements, if appropriate crop is grown based on the characteristics of wastewater, the problem can be avoided. Table J.6 shows salt tolerance of landscape plants. Table J.7 shows relative boron tolerance of agricultural crops and landscape plants. Table J.8 shows chloride tolerance of some fruit crops and rootstocks.

1.4.2 Industrial Reuse

Problem of scale formation can be prevented by controlling the formation of $Ca_3(PO_4)_2$ which is the first Calcium salt to precipitate, if phosphate is present. Removal of phosphates by precipitation is the most common treatment. Other treatment such as ion exchange can also reduce scale formation by removing calcium and magnesium, but is expensive and use is limited.

The corrosion potential of cooling water can be controlled by corrosion inhibitors. By addition of biocide or acid biological growth can be controlled. The addition of chemical dispersents, that prevent particles from aggregating and subsequently settling, prevent fouling. Also chemical coagulation and filtration required for phosphorous removal, are effective in reducing the concentration of contaminants that contribute to fouling.

2. Sludge Reuse

Sludge is the concentrated particulate organic fraction produced during sewage treatment. Its physical properties and chemical composition vary quite widely according to the source, the stage of sewage treatment from which it is produced and the way in which it is treated. Biological treatment has been proposed for the Texcoco treatment plant, sludge produced contains mainly biological solids and have a lower content of dry solids than primary sludge.

At present sludge treatment is not being practiced in the existing treatment plants, however in the proposed Texcoco treatment plant, sludge is proposed to be digested anaerobically before disposal. Digested sludge is stabilized sludge and can be reused for beneficial purposes after dewatering.

Sludge reuse can be broadly categorized into three categories.

1) Land Application
2) Construction Material
3) Fuel/Heating purpose

Fig. J.2 shows the type of sludge required for different type of reuse purpose.

Texcoco Treatment Plant employs digestion process, hence digested sludge after drying can be reused for land application or for fuel/heating purpose. In the Feasibility Report, treated sludge is proposed to be land disposed and methane gas is proposed to be utilized as energy for the blowers in aeration tank. However, this guideline manual explain briefly various possible reuses of treated sludge.

2.1 Land Application

Application of sludge to the land for beneficial purposes is termed as land application. These beneficial purposes include, application for growing variety of crops, spreading of sludge in pastures or tree farms, application of sludge for reclaiming land such as old mining sites. All of the above mentioned land application methods use the beneficial aspects of sludge, even though some may not involve crops or animal production, but eventually become part of the human food chain.

EPA has established criteria for the use of processed sludge on agricultural land. After the sludge is treated by the treatment process to significantly reduce pathogens (PSRP) it can be applied to the agricultural land. Figure J.3 shows the EPA regulations for using processed sludge on agricultural land.

Composting is included in the category of the treatment process to further reduce pathogens, hence seems to be appropriate process for applying sludge of domestic wastewater to the agricultural land. The flow of composting process is shown in Fig J.4.

2.2 Animal Feed Production

Sludge mixed with other feed components has been fed to the sheep and cattle in United States. Sludge was irradiated by gamma rays to destroy parasites and pathogens. Research shows, slight difference in iron and lead content of the animal's livers and kidneys, however value of these metals and halogenated hydrocarbons were well within the range when compared with conventionally fed animals.

2.3 Biobrick Production

Municipal wastewater sludge may be substituted for other organic substances, such as sawdust, normally used in the production of building bricks. The high temperature to which the bricks are subjected in the kiln destroys all organic matter in the sludge, including pathogenic organisms. The bricks so produced are nearly identical to ordinary bricks by all measurable standards and are called biobricks. The finished bricks have the look, feel and smell of ordinary bricks and meet all ASTM requirements for strength and other properties. The bricks have been also tested by the extraction procedure test for leaching and have been judged satisfactory.

2.4 Cement from Sludge

This process uses activated sludge that is flocculated with sequential additions of carbon dioxide and calcium dioxide. The flocculated sludge is filtered and fed to a cement Kiln. Then the resultant clinker is ground with gypsum to produce a cement which is in the Portland range of composition.

2.5 Earthworm Conversion (Vermiculture)

Earthworm conversion is a stabilization process by which earthworms consume the organic material in a municipal sludge. The product of vermiculture (that is worm castings) may be used as soil conditioner, while the worms may be used as animal feed. Before the castings can be used, they must be separated from the worms by screening.

2.6 Fuel from Sludge

A reactor has been developed in Germany, to convert sludge to liquid and solid fuel. In this process dried sludge is heated between 300-350 ^{0}C in an oxygen free environment for approximately 30 minutes. The final volume of oil and char produced is less than the original sludge and a net energy production results from the process. The Canadian investigators have also obtained the same results and have reported that the oil produced meets ASTM standards for No. 5 fuel oil, which may be used in heavy industrial applications such as boilers and blast furnaces. Emissions from the process include noncondensible gases and pyrolytic water.

2.7 Aggregate Production

In United States, another beneficial use of sludge is the production of aggregate from the sludge. A process called "Ecorock" that uses ash from incinerated sludge and municipal solid waste to produce a hard, dense rock has been developed. The process first incinerates dewatered sludge and ground municipal refuse in a rotary kiln. The ash produced is then fused in a furnace at 1092°C forming a rock suitable for use as a road aggregate. The main advantage of Ecorock production as a sludge utilization alternative is that the sludge is completely utilized in the production of a useful and marketable material with minimal sidestream production. The main disadvantages are the unknown marketability of large quantities of the Ecorock product and the unproven reliability of this technology due to limited operating experience.

3. Advanced Wastewater Treatment Processes

Wastewater reuse has become almost necessary in the study area due to scarcity of water. At present also treated wastewater is being reused in D.F. Mexico for conventional reuses such as agricultural irrigation, landscape irrigation, lake refilling and industrial purposes. However it has been described in Reuse Master Plan that in near future Mexico is planning to extend the reuse of treated wastewater to non conventional reuses such as groundwater recharging, non potable municipal reuses and so on. However using treated wastewater for non conventional reuses require strict quality control and advanced wastewater treatment of the wastewater.

The proposed Texcoco wastewater treatment plant is designed to have biological wastewater treatment process intendeed to remove organic compounds, however reusing treated water for non conventional reuses will require advanced treatment process.

The major concern with groundwater recharge with reclaimed wastewater is that potentially adverse health effects may be caused by the introduction of pathogens or trace amounts of toxic contaminants. Because of the increasing concern for long-term health effects, every effort should be made to reduce the number of chemical species and the concentration of specific organic constituents in the recharge water. Fig J.5 shows schematic diagram of the wastewater treatment process required for producing water suitable for groundwater recharging.

Fig J.6 depicts a schematic diagram of treatment system that should produce water satisfactory for a recreational lake. The process includes nitrification and removal of phosphorous compounds down to the level of about 0.1 mg of phosphorous per liter.

For reusing treated wastewater for non-potable/potable water supply, three classes of contaminants are of special concern; viruses, organic contaminants including pesticides and heavy metals. To accomplish the high degree of treatment and reliability for potable reuse, advanced unit operations and processes often include lime clarification, nutrient removal, recarbonation, filtration, activated carbon adsorption, demineralization by reverse osmosis and disinfection by chlorine/ozone. A conceptual flow diagram of an advanced wastewater treatment process combination capable of producing potable water from municipal wastewater is illustrated in Fig. J.7.

4. Comparison of Helminth Eggs Removal Efficiency

As described in WHO manual, the better way is to study the pathogen survival rather than pathogen removal because health hazards are posed by the pathogens that survive a treatment process, not by those that are removed by treatment. Figures such as 99 % or 99.9 % removal appear highly impressive but represent 1 to 0.1 % survival respectively, and this degree of survival may be highly significant where incoming concentrations are great. If an influent contains 10^5 pathogens then 99 % removal will produce an effluent with 10^3 pathogens. And in areas where the effluent is to be reused or where it is to be discharged to a stream, the effluent quality may be inadequate.

The removal efficiency of helminth eggs of various processes, as reported in the literature and WHO manuals is described below.

Process	Bacteria removal Efficiency (%)	Helminth removal Efficiency (%)
Primary Sedimentation	0 - 90	0 - 99
Activated Sludge	0 - 99	0 - 99
Biofilter	0 - 99	0 - 99
Aerated Lagoon	0 - 99	90 - 99.9
Disinfection	99 - 99.9999	0 - 90
Stabilization ponds	90 - 99.9999	90 - 99.9

Another set of data also shows the same trend with higher helminth removal efficiency in stabilization process.

Process	Bacteria removal Efficiency (%)	Helminth removal Efficiency (%)
Primary Sedimentation	20 - 60	20 - 60
Activated Sludge	80 - 90	80 - 90
Biofilter	80 - 90	80 - 90
Stabilization ponds	99.99	99.99

5. Comparison of Wastewater Treatment System with and without Primary Sedimentation Tank for the Final Project

(1) General

In this section, following two (2) wastewater treatment processes for the final project are financially evaluated.

- Treatment process with primary sedimentation tank (With PST)
- Treatment process without primary sedimentation tank (Without PST)

With PST process can remove influent BOD of about 20% at the primary sedimentation tank, while aeration tank of without PST process receives all influent BOD. Hence treatment process without PST requires larger volume of aeration tank and larger capacity of blower than those of treatment process with PST.

(2) Design Conditions of Comparative Evaluation

Following design conditions are used for the comparative evaluation.

Wastewater Quantity	:	5 m^3/sec.	
Influent Wastewater Quality	:	BOD_5	= 245 mg/l
		SS	= 260 mg/l
Treated Water Quality	:	BOD_5	= 20 mg/l
		SS	= 30 mg/l
Removable Efficiency of PST	:	BOD_5	= 20%
		SS	= 40%
Overflow Rate of PST	:	35 m^3/m^2.d	
F/M Ratio	:	0.3	
MLSS/MLVSS Ratio	:	0.75	
Sludge Recirculation Ratio	:	0.35	
SS of Return Sludge	:	8,000 mg/l	

For the liquid treatment process, both processes require the same capacity of secondary sedimentation tank. Then the secondary sedimentation tank is neglected from the comparison of both treatment processes.

Solid balance of both with PST and without PST processes are described in Fig. J.8 and Fig. J.9. From these two (2) figures, both processes require the same capacity of anaerobic digester and mechanical dewatering systems. Then for the sludge treatment process, only thickening system is compared.

(3) Structure Design

Each facility of both with PST process and without PST process are compared as shown below.

Facility	With PST	Without PST
Primary Sedimentation Tank	Width : 5.0 m Length : 39.0 m Depth : 3.0 m Number of Channel : 64	-
Aeration Tank	Width : 10.3 m Length : 89.0 m Depth : 6.0 m Number of tank : 32 Capacity : 170,310 m^3	Width : 10.3 m Length : 110.0 m Depth : 6.0 m Number of tank : 32 Capacity : 210,496 m^3
Blower	640 m^3/min x 900 kw 4 sets	650 m^3/min. x 920 kw 5 sets
Gravity Thickener	Ø 19 m x 2 tanks	-
Centrifugal Thickener	170 m^3/hr. x 3 sets	170 m^3/hr. x 5 sets

(4) Construction Cost and O/M Cost

Construction cost of both treatment processes are estimated as shown below.

With PST process

(Unit : million N$)

	Civil/Architect	Mecha./Elec.	Total
PST	32.1	20.83	52.93
AT	67.1	26.3	93.4
Blower	5.7	21.6	27.3
GT	3.4	1.8	5.2
CT	7.2	11.7	18.9
Total	115.5	82.23	197.73

Note : PST : Primary Sedimentation Tank, AT : Aeration Tank, GT : Gravity Thickener, CT : Centrifugal Thickener

Without PST process

(Unit : million N$)

	Civil/Architect	Mecha./Elec.	Total
AT	88.0	34.6	122.6
Blower	6.1	27.5	33.6
CT	9.5	19.5	29.0
Total	103.6	81.6	185.2

Note : AT : Aeration Tank, CT : Centrifugal Thickener

Electrical expenditure is considered as the major O/M cost involved.

Annual electrical expenditure of both processes are estimated as follows.

With PST process : 5.37 N$ million
Without PSTprocess : 8.20 N$ million

(5) Financial Evaluation

Both with PST process and without PST process are compared in terms of required construction cost and O/M cost as described below.

	Construction Cost (N$ million)	Annual Electrical Expenditure (N$ million/annum)
With PST	197.73	5.37
Without PST	185.2	8.20

Construction cost of with PST process is about 12.53 N$ million more than that of without PST process. Whereas without PST process requires the annual electricity charge of 2.83 N$ million more than that of with PST process.

Construction cost and O/M cost of these two (2) processes, for the project life time are compared, in terms of present values, estimated based on the same assumption as mentioned in Chapter 5.

The construction and O/M cost of two (2) processes are compared in terms of present values as shown below:

(Unit : N$ million)

	Construction Cost	Electrical Expenditure	Total
With PST	200	50	250
Without PST	188	78	266

As evident from the above table, with PST process is more economical than without PST process.

Hence with PST process is proposed as the wastewater treatment process for the final project.

References

1. Irrigation with reclaimed municipal wastewater, a guidance manual; California State Water Resources Control Board.

2. Wastewater Engineering: treatment, disposal and reuse; Metcalf and Eddy.

3. Design of municipal wastewater treatment plants; WEF manual of practice No. 8, ASCE manual and report on engineering practice No. 76.

4. Reuse of Effluents: Methods of Wastewater treatment and health safeguards; WHO Technical report series No 517.

5. The risk to health of microbes in sewage sludge applied to land; WHO Euro reports and studies No 54.

6. Health guidelines for the use of wastewater in agriculture and aquaculture: WHO Technical report series 778.

7. Health aspects of treated sewage reuse; WHO Euro report and studies No 42.

8. Productive use of human waste; World Bank technical report.

9. Health effects relating to direct and indirect reuse of waste water for human consumption WHO technical paper series 7.

Table J.1 Guidelines for Interpretations of Water Quality for Irrigation

Potential Irrigation Problem	Units	Degree of Restriction on Use		
		None	Slight to Moderate	Severe
Salinity (affects crop water availability)				
EC_w	dS/m or mmho/cm	<0.7	0.7-3.0	>3.0
TDS	mg/L	<450	450-2,000	>2,000
Permeability (affects infiltration rate of water into the soil. Evaluate using EC_w and SAR or adj R_{Na} together)				
SAR = 0-3		and ECw ≥0.7	0.7-0.2	<0.2
3-6		≥1.2	1.2-0.3	<0.3
6-12		≥1.9	1.9-0.5	<0.5
12-20		≥2.9	2.9-1.3	<1.3
20-40		≥5.0	5.0-2.9	<2.9
Specific ion toxicity (affects sensitive crops)				
Sodium (Na)				
Surface Irrigation	SAR	<3	3-9	>9
Sprinkler Irrigation	mg/L	<70	>70	
Chloride (Cl)				
Surface Irrigation	mg/L	<140	140-350	>350
Sprinkler Irrigation	mg/L	<100	>100	
Boron (B)	mg/L	<0.7	0.7-0.3	>3.0
Miscellaneous effects (affects susceptible crops)				
Nitrogen (Total-N)	mg/L	<5	5-30	>30
Bicarbonate (HCO_3) (overhead sprinkling only	mg/L	<90	90-500	>500
pH	unit		Normal range 6.5-8.4	
Residual chlorine (overhead sprinkling only)	mg/L	<1.0	1.0-5.0	>5.0

Table J.2 Recommended Maximum Concentrations of Trace Elements in Irrigation Waters

Element	Recommended Maximum Concentration[a], mg/L	Remarks
Al (aluminum)	5.0	Can cause nonproductivity in acid soils (pH < 5.5), but more alkaline soils at pH > 5.5 will precipitate the ion and eliminate any toxicity.
As (arsenic)	0.10	Toxicity to plants varies widely, ranging from 12mg/L for Sudan grass to less than 0.05mg/L for rice.
Be (beryllium)	0.10	Toxicity to plants varies widely, ranging from 5mg/L for kale to 0.5 mg/L for bush beans.
Cd (cadmium)	0.010	Toxic to beans, beets, and turnips at concentrations as low as 0.1 mg/L in nutrient solutions. Conservative limits recommended because of its potential for accumulation in plants and soils to concentrations that may be harmful to humans.
Co (cobalt)	0.050	Toxic to tomato plants at 0.1 mg/L in nutrient solution. Tends to be inactivated by neutral and alkaline soils.
Cr (chromium)	0.10	Not generally recognized as an essential growth element. Conservative limits recommended because of lack of knowledge on toxicity to plants.
Cu (copper)	0.20	Toxic to a number of plants at 0.1 to 1.0 mg/L in nutrient solutions.
F (fluoride)	1.0	Inactivated by neutral and alkaline soils.
Fe (iron)	5.0	Not toxic to plants in aerated soils but can contribute to soil acidification and loss of reduced availability of essential phosphorus and molybdenum. Overhead sprinkling may result in unsightly deposits on plants, equipment, and buildings.
Li (lithium)	2.5	Tolerated by most crops up to 5 mg/L ; mobile in soil. Toxic to citrus at low levels (> 0.075 mg/L). Acts similar to boron.
Mn (manganese)	0.20	Toxic to a number of crops at a few tenths mg to a few mg/L, but usually only in acid soils.
Mo (molybdenum)	0.010	Not toxic to plants at normal concentrations in soil and water. Can be toxic to livestock if forage is grown in soils with high levels of available molybdenum.
Ni (nickel)	0.20	Toxic to number of plants at 0.5 to 1.0 mg/L ; reduced toxicity at neutral or alkaline pH.
Pb (lead)	5.00	Can inhibit plant cell growth at very high concentrations.
Se (selenium)	0.020	Toxic to plants at concentrations as low as 0.025 mg/L and toxic to livestock if forage is grown in soils with relatively high levels of added selenium. An essential element for animals but in very low concentrations.
Sn (tin)	-	Effectively excluded by plants ; specific tolerance unknown.
Ti (titanium)	-	(See remark for tin)
W (tungsten)	-	(see remark for tin)
V (vanadium)	0.10	Toxic to many plants at relatively low concentrations.
Zn (zinc)	2.0	Toxic to many plants at widely varying concentrations ; reduced toxicity at pH>6.0 and in fine-textured or organic soils.

a The maximum concentration is based on a water application rate that is consistent with good agricultural practice (4 ft/yr).

Table J.3 Water Quality Requirements at Point of Use for Steam Generation and Cooling in Heat Exchangers

	Boiler feedwater				Cooling water			
	Quality of water prior to the addition of chemicals used for internal conditioning							
	Industrial			Electrical utilities	Once through		Make-up for recirculation	
Characteristic	Low Pressure	Intermediate pressure	High pressure		Fresh	Brackish[a]	Fresh	Brackish[a]
Silica (SiO_2)	30	10	0.7	0.01	50	25	50	25
Aluminum (Al)	5	0.1	0.01	0.01	b	b	0.1	0.1
Iron (Fe)	1	0.3	0.05	0.01	b	b	0.5	0.5
Manganese (Mn)	0.3	0.1	0.01	0.01	b	b	0.5	0.02
Calcium (Ca)	b	0.4	0.01	0.01	200	420	50	420
Magnesium (Mg)	b	0.25	0.01	0.01	b	b	b	b
Ammonia (NH_4)	0.1	0.1	0.1	0.07	b	b	b	b
Bicarbonate (HCO_3)	170	120	48	0.5	600	140	24	140
Sulfate (SO_4)	b	b	b	d	680	2,700	200	2,700
Chloride (Cl)	b	b	b	b,d	600	19,000	500	19,000
Dissolved solids	700	500	200	0.5	1,000	35,000	500	35,000
Copper (Cu)	0.5	0.05	0.05	0.01	b	b	b	b
Zinc (Zn)	b	0.01	0.01	0.01	b	b	b	b
Hardness ($CaCO_3$)	350	1.0	0.07	0.07	850	6,250	650	6,250
Alkalinity ($CaCO_3$)	350	100	40	1	500	115	350	115
pH, units	7.0-10.0	8.2-10.0	8.2-9.0	8.8-9.4	5.0-8.3	6.0-8.3	b	b
Organics:								
Methylene blue active substances	1	1	0.5	0.1	b	b	1	1
Carbon tetrachoride extract	1	1	0.5	b,c	e	e	1	2
Chemical oxygen demand (COD)	5	5	1.0	1.0	75	75	75	75
Hydrogen sulfide (H_2S)	b	b	b	b	-	-	b	b
Dissolved oxygen (O_2)	2.5	0.007	0.007	0.007	present	present	b	b
Temperature	b	b	b	b	b	b	b	b
Suspendid solids	10	5	0.5	0.05	5,000	2,500	100	100

Note: Unless otherwise indicated, units are mg/l and values that normally should not be exceeded. No one water will have all the maximum values shown.

a Brackish water - dissolved solids more than 1000 mg/L.
b Accepted as received (if meeting other limiting values) ; has never been a problem at concentrations encountered.
c Zero, not detectable by test.
d Controlled by treatment for other constituents.
e No floating oil.

Table J.4 Factors to be Considered in the Formulation of Groundwater Recharge Guidelines in the United States

Surface spreading	
Treatment	Source control of toxic chemicals
	Primary sedimentation and secondary biological treatment
	Tertiary granular-medium filtration (possibly, activated-carbon adsorption for organics removal)
	Disinfection
Depth to groundwater	Percolation through an unsaturated zone of undisturbed soil
	Depth to groundwater in the range of 10 to 50 ft depending on percolation rate of the soils
Retention time in ground	6 to 12 months depending on the type of pretreatment
Maximum percent reclaimed wastewater	20 to 50% on the annual basis at extraction wells, depending on organics removal
Horizontal distance	500 to 1000 ft depending on pretreatment
Monitoring	Extensive including the contaminants in the drinking water regulations
Direct injection	
Treatment	Source control of toxic chemicals
	Primary sedimentation and secondary biological treatment
	Chemical coagulation, clarification, and granular-medium filtration
	Activated-carbon adsorption
	Volatile organics removal
	Reverse osmosis or other membrane process
	Disinfection
Depth to groundwater	Not applicable (direct injection to groundwater aquifers)
Retention time in ground	12 months
Maximum percent reclaimed wastewater	20% on the annual basis at extraction wells
Horizontal distance	1000 to 2000 ft
Monitoring	Quite extensive including the contaminants in the drinking water regulations

Table J.5 Quality of Water from Renovation System for Producing Potable Water

	Concentration in effluent[a] (mg/l)	United States Public Health Service drinking-water standard (mg/l)
Chemical oxygen demand	5	-
Coliform organisms (mean density)	Effluent breakpoint chlorinated	1/100 ml
Turbidity	< 1 unit	5 units
Colour	< 2 units	15 units
Threshold odour number	No odour	3
Methylene blue active substances	< 0.5	0.5
Chloride	< 250	250
Carbon chloroform extract	< 0.05	0.2
Cyanide	0	0.01
Iron	< 0.3	0.3
Manganese	< 0.05	0.05
Nitrate (NO_3)	< 45	45
Phenols	0	0.001
Phosphorus	< 0.5	-
Sulfate (SO_4)	< 250	250
Total dissolved solids	< 500	500

a The values given are a combination of results from a number of pilot studies (primarily the study at Pomona, California) and from the advanced waste-treatment plant at South Lake Tahoe, California.

Table J.6 Relative Salt Tolerance of Landscape Plans [a]

Very sensitive[b]
(Max. EC_W = 0.7-1.4 mmho/cm or ds/m)

Star Jasmine (Trachelospermum Jasminoides)
Pyrenees Contoneaster (Cotoneaster congestus)
Oregon grape (Mahonia Aquifolium)
Photinia (Photinia x Fraseri)

Sensitive[b]
(Max EC_w = 1.4-2.7 mmho/cm or ds/m)

Pineapple guava (Feiojoa Sellowiana)
Chinese holly, cv. Burford (I lex cornuta)
Rose, cv. Grenoble (Rosa sp.)
Glossy abelia (Abelia x grandiflora)
Southern yew (Podocarpus macrophyllus)
Tulip tree (Liriodendron Tulipifera)
Algerian ivy (Hedera canariensis)
Japanese Pittosporum (Pittosporum Tobira)
Heavenly bamboo (Nandina domestica)
Chinese hibiscus (Hibiscus Rosa-sinensis)
Laurustinus, cv. Robustum (Viburnum Tinus)
Strawberry tree, cv. Compact (Arbutus Unedo)
Crape Myrtle (Lagerstroemia indica)

Modrately Sensitive[b]
Max. EC_w = 2.7-4.0 mmho/cm or ds/m)

Glossy privet (Ligustrum lucidum)
Yellow sage (Lantana camara)
Orchid tree (Bauhinia purpurea)
Southern Magnolia (Magnolia grandiflora)
Japanese boxwood (Buxus microphylla var. japonica)
Dodonaea, cv. atropurpurea (Dodonaea Viscosa)
Oriental arborvitae (Platycladus orientalis)

Medrately Sensitive[b] (Continued)

Thorny elaeagnus (Elaeagnus pungens)
Spreading juniper (juniperus chinensis)
Xylosma (Xylosma congestum)
Japanese black pine (Pinus Thunbergiana)
Indian Hawthorn (Raphiolepis indica)
Pyracantha, cv. Graberi (Pyracantha Fortuneana)
Cherry plum (Prunes cerasifera)

Moderately tolerant[b]
(Max. EC_w = 4.0-5.5 mmho/cm or dS/m)

Weeping bottlebrush (Callistemon viminalis)
Oleander (Nerium oleander)
European fan plam (Chamaerops humilis)
Blue dracaena (Cordyline indivisa)
Spindle tree, cv. Grandiflora (Euonymus japonica)
Rosemary (Rosmarinus officinalis)
Aleppo pine (Pinus halepensis)
Sweet gum (Liquidambar Styraciflua)

Tolerant[b]
(Max. EC_w > 5.5 mmho/cm or dS/m)

Brush cherry (Syzygium paniculatum)
Ceniza (Leucophyllum frutescens)
Natal plum (Carissa grandiflora)
Evergreen Pear (Pyrus Kawakamii)
Bougainvillea (Bougainvillea spectabilis)
Italian stone pine (Pinus pinea)

Very tolerant[b]
(Max. EC_w > 6.8 mmho/cm or dS/m)

White iceplant (Delosperma alba)
Rosea iceplant (Drosanthemum hispidum)
Purple iceplant (Lampranthus productus)
Croceum Iceplant (Hymenocyclus croceus)

a. Species are listed in order of increasing tolerance based on appearance as well as growth reduction.
b. EC_w= Electrical conductivity of the irrigation water. Salinities exceeding the maximum permissible water salinity (Max. EC_w) may cause leaf burn, loss of leaves, and /or excessive stunting. The maximum values shown were derived from maximum permissible EC_e data by a factor of EC_e = 1.5 EC_w. This relationship should be valid for normal irrigation practices. The electrical conductivity of the irrigation water can be designated as MPH/cm. or dS/m.

Table J.7 Relative Boron Tolerance of Agricultural Crops and Landscape Plants.[a]

Agricultural crops

Very sensitive (<0.5 mg/L)

- Lemon (Citrus Limon)
- Blackberry (Rubus sp.)

Sensitive (0.5 - 1.0 mg/L)

- Avocado (persea americana)
- Grapefruit (Citrus x paradisi)
- Orange (Citrus sinensis)
- Apricot (Prunus armeniaca)
- Peach (Prunus persica)
- Cherry (Prunus avium)
- Plum (Prunus domestica)
- Persimmon (Diospyros Kaki)
- Fig. Kadota (Ficus carica)
- Grape (Vitis vinifera)
- Wailnut (Juglans regia)
- Pecan (Carya illinoinensis)
- Cowpea (Vigna unguiculate)
- Onion (Allium Cepa)
- Garic (Allium Sativum)
- Sweet potato (Ipomea Batatas)
- Wheat (triticum aestivum)
- Barley (Hordeum vulgare)
- Sunflower (Helianthus annus)
- Bean. mung (Vigna radiata)
- Seame (Sesanum indicum)
- Lupine (Lupinus Hartwegii)
- Strawberry (Fragaria sp.)
- Artichoke. Jerusalem (Helianthus tuberosus)
- Bean. Kidney (Phaseolus vulgaris)
- Bean. Lima (Phaseolus Lunatus)
- Peanut (Arachis hypoquea)

Moderately Sensitive (1.0-2.0 mg/L)

- Pepper, red (Capsicum annuum)
- Pea (Pisum sativa)
- Carrot (Daucus carota)
- Radish (Raphanus sativus)
- Potato (Solanum tuberosum)
- Cucumber (Cucmis sativus)

Moderately tolerant (2.0-4.0 mg/L)

- Lettuce (Lactuca sativa)
- Cabbage (Brassica oleracea capitata)
- Celery (Apium graveolens)
- Turnip (Brassica rapa)
- Bluegrass, kentucky (pon pratensis)
- Oats (Avena sativa)
- Corn (Zea mays)
- Artichoke (Cynara Scolymus)
- Tobacco (Nicotiana Tabacum)
- Mustard (Brassica juncea)
- Clover, sweet (Melilotus indica)
- Squash (Cucurbita pepo)
- Muskmelon (Cucumis melo)

Tolerant (4.0-6.0 mg/L)

- Sorghum (Sorghum bicolor)
- Tomato (Lycopersican Lycopersicvm)
- Alfalfa (Medicago sativa)
- Vetch, porple (Vicia benghalensis)
- Parsley (Petroselinum crispum)
- Beet, red (Beta vulgaris)
- Sugarbeet (Beta vulgaris)

Very tolerant (6.0-15.0 mg/L)

- Cotton (Bossypium Hirsutum)
- Asparagus (Asparagus officinalis)

Ornamentals

Very sensitive (<0.5 mg/L)

- Oregon grape (Mahonia Aquifolium)
- Photinia (Photinia x Frasari)
- Xylosma (Xylosma congestum)
- Thorny elaeagnus (Elaeagnus pungens)
- Laurustinus (Viburnum Tinus)
- Wax-Leaf privet (Ligustrum japonicum)
- Pineapple guava (feijoa sellowiana)
- Spindle tree (Euonymus japonica)
- Japanese pittosporum (Pittosporum Tobira)
- Chines holly (Ilex cornuta)
- Juniper (Juniperus chinensis)
- Yellow sage (Lantana Camara)
- American elm (Ulmus americana)

Sensitive (0.5 - 1.0 mg/L)

- Zinnia (Zinnia elegans)
- Pansy (Viola tricolor)
- Violet (Viola odorata)
- Larkspur (Delphinum sp.)
- Glossy abelia (Abelia x grandiflora)
- Rosemary (Rosemarinus officinalis)
- Oriental arborvitae (Platycladus orientalis)
- Geranium (Pelargonium x hortorum)

Moderately sensitive (1.0-2.0 mg/L)

- Gladioli (Gladiolus sp.)
- Marigold (Calendula officinalis)
- Poinsettia (Euphorbia pulcherrima)
- China aster (Callistephus chinensis)
- Gardenia (Gardenia sp.)
- Southrn yew (Poducarpus Macrophyllus)
- Bruch cherry (Syzygium pniculatum)
- Blue dracaena (Cordylin indivisa)
- Ceniza (Leucophyllum Frutescens)

Moderately tolerant (2.0-4.0 mg/L)

- Bottlebrush (Callistemon citrinus)
- California poppy (Eschscholizia californica)
- Japanese boxwood (Buxus microphylla)
- Oleander (Merium Oleander)
- Chinese nibiscus (Hibiscus Rosasinensis)
- Sweetpea (Lathyrus odoratus)
- Carnation (Dianthus Caryophyllus)

Tolerant (6.0-8.0 mg/L)

- Indian hawthorn (raphiolepis indica)
- Natal plum (Carissa grandiflora)
- Oxalis (Oxalis Bowiei)

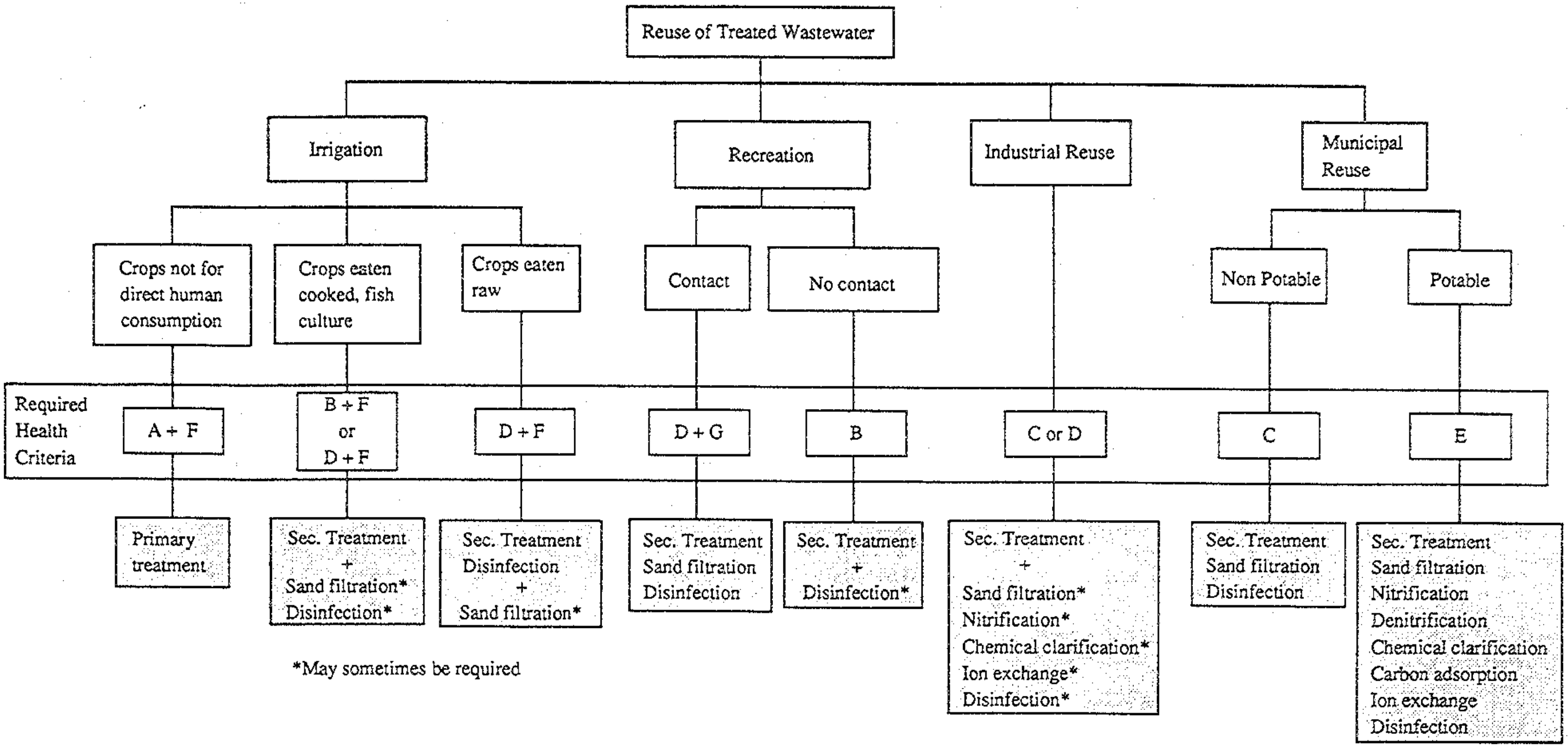
a. Maximum concentrations tolerated in soil water without yield or vegetative growth reductions. Boron tolerances very depending upon climate soil conditions and crop varieties. Maximum concentrations tolerated in the applied irrigation water are approximately equal to these values for soil-water or slightly less.

Table J.8 Chloride Tolerance of Some Fruit Crop Cultivars and Rootstocks

Crop	Rootstock or cultivar	Maximum permissible Cl in water without leaf injury[a,b] (mg/l)
	Rootstocks	
Avocado (persea americana)	West Indian	180
	Guatemalan	145
	Mexican	110
Citrus (Citrus spp.)	Sunki mandarin, grapefruit Cleopatra mandarin, Rangpur lime	600
	Sampson tangelo, rough lemon, sour orange, Ponkan mandarin	355
	Citrumelo 4475, trifolate orange, Cuban shaddock, Calamondin, sweet orange, Savage citrange, Rusk citrange, Troyer citrange	250
Grape (Vitis spp.)	Salt Creek, 1613-3	960
	Dog ridge	710
Stone fruit (Prunus spp.)	Marianna	600
	Lovell, Shalil	250
	Yunnan	180
	Cultivars	
Berries (Rubus spp.)	Boysenberry	250
	Olallie blackberry	250
	Indian Summer raspberry	110
Grape (Vitis spp.)	Thompson seedless, Perlette	460
	Cardinal, black rose	250
Strawberry (Fragaria spp.)	Lassen	180
	Shasta	110

a. For some crops, the concentrations given may exceed the overall salinity tolerance of that crop and cause some yield reduction before chloride ion toxicities. Values given are for the maximum concentration in the irrigation water. The values were derived from saturation extract data (EC) by the following relationship: Saturation extraction concentration = 1.5 water concentration.

b. The maximum permissible values apply only to surface irrigated crops. Sprinkler irrigation may cause excessive leaf burn at values far below these



Health Criteria

A Free from gross solids, significant removal of parasite eggs
B As 'A' plus significant removal of bacteria
C As 'A' plus more effective removal of bacteria plus some removal of virus
D Not more than 100 Coliform Organisms per 100 ml in 80% of samples
E No fecal Coliform organisms in 100 ml, plus no virus particles in 1000 ml, plus no toxic effects on man & other drinking criteria.
F No chemicals that lead to Undesirable residues in crops or fish
G No chemicals that lead to irritation of mucous membrane of skin

Fig. J.1 WHO Guidelines for Treatment Processes to Meet the Given Health Criteria for Wastewater Reuse

THE FEASIBILITY STUDY ON WASTEWATER TREATMENT IN THE FEDERAL DISTRICT OF MEXICO

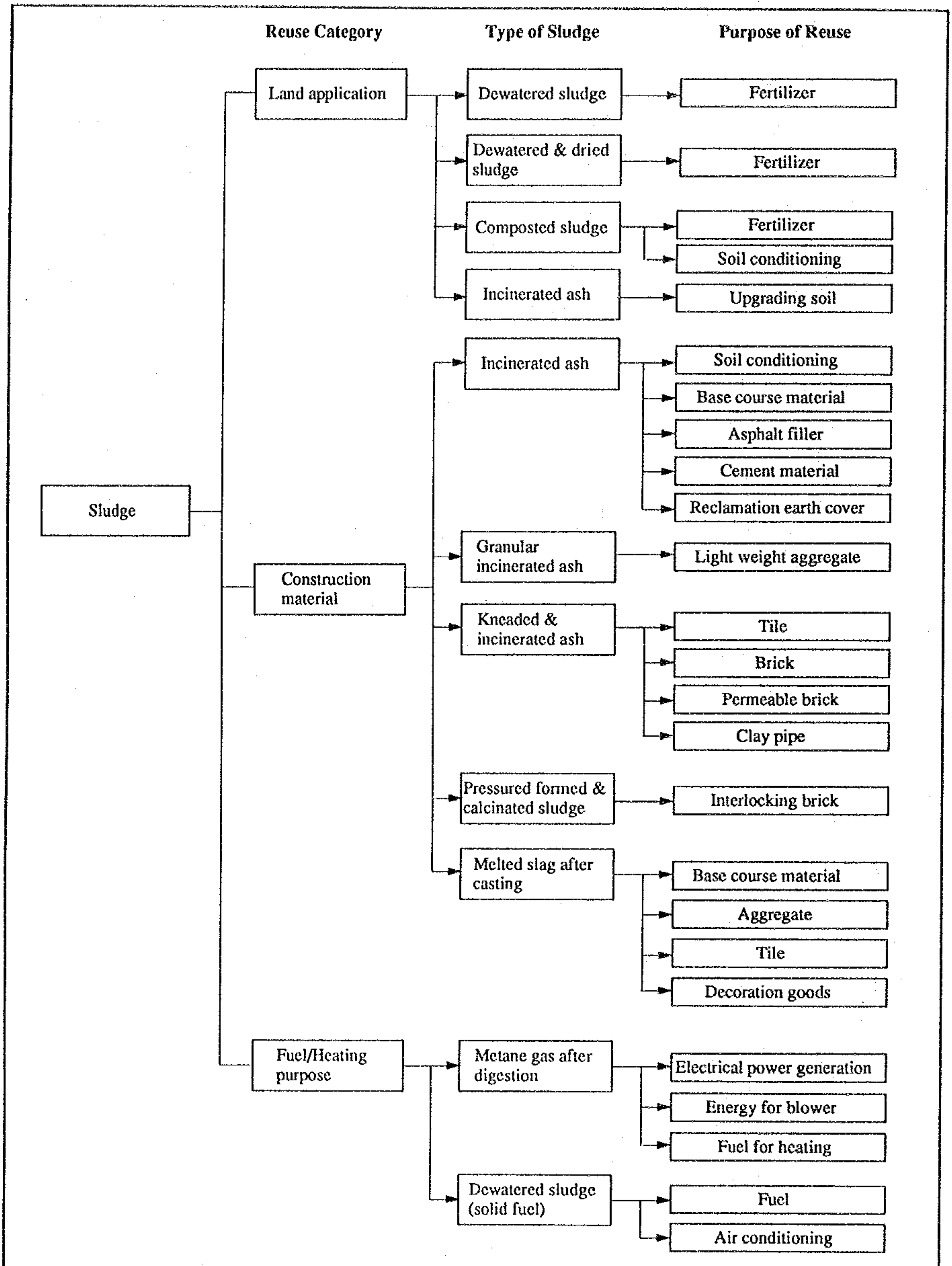
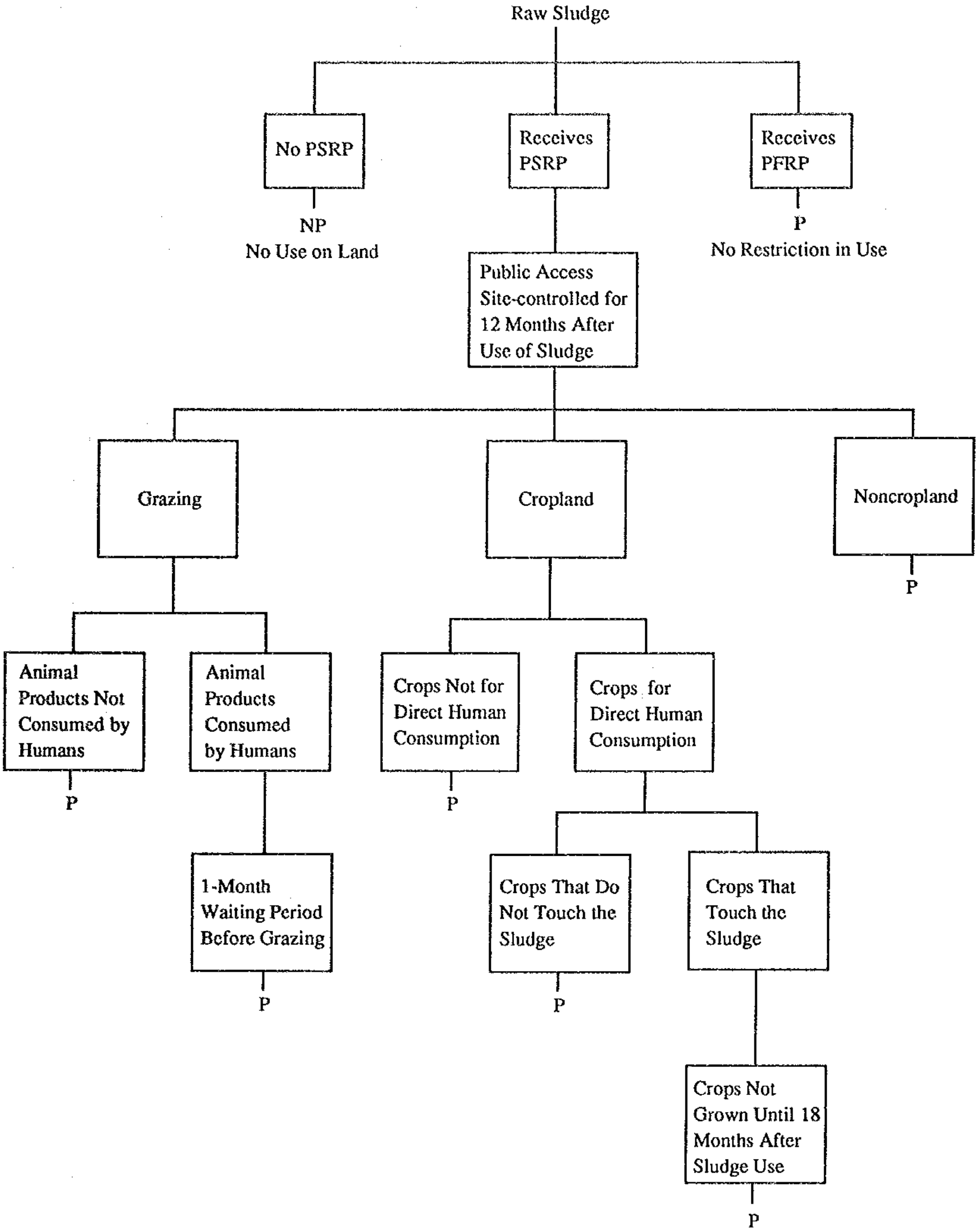


Fig. J.2 Type of Sludge Required for Different Type of Reuse Purpose



P = permitted
NP = not permitted
PSRP = process to significantly reduce pathogens (aerobic digestion, anaerobic digestion, air drying, lime stabilization)
PFRP = process to further reduce pathogens (composting, heat drying, heat treatment, thermophilic aerobic digestion)

Fig. J.3 EPA Regulations for Using Processed Sludges on Agricultural Land

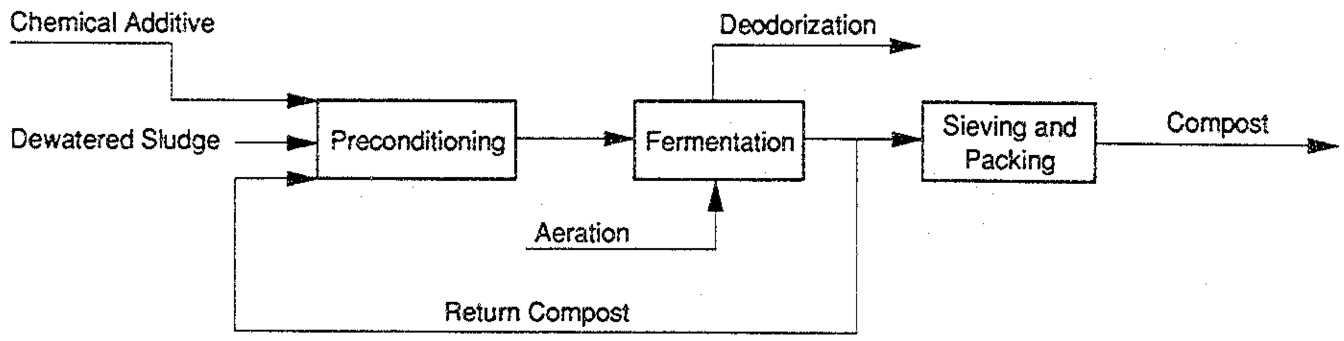


Fig. J.4 Schematic Flow of Composting Process

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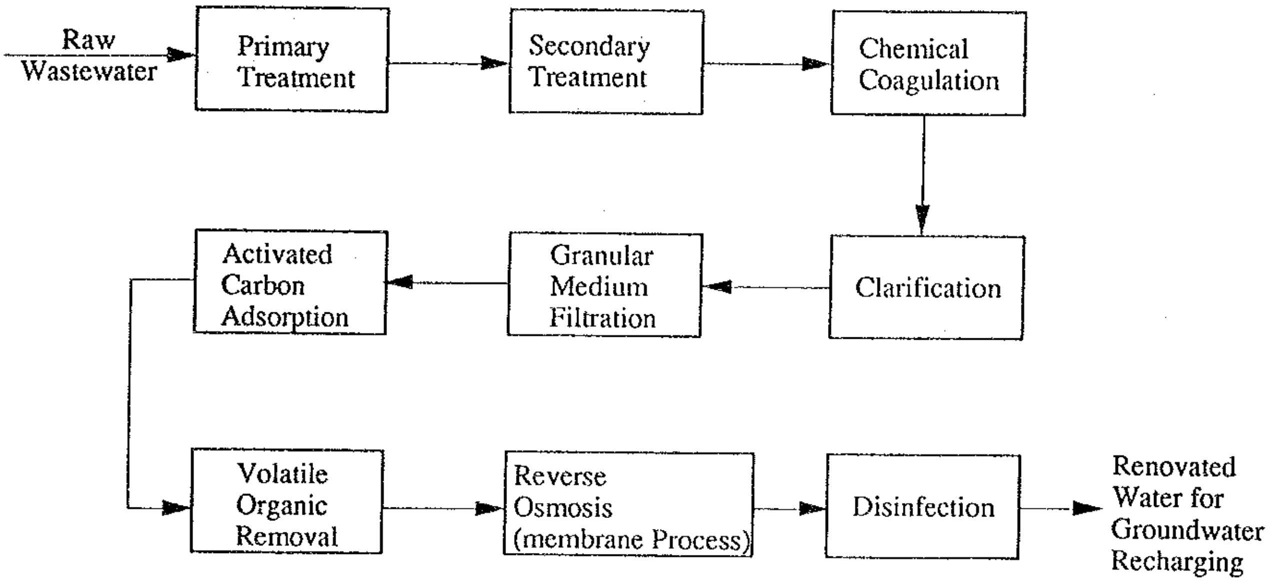

Fig. J.5 Treatment System for Producing Renovated Water Suitable for Groundwater Recharging

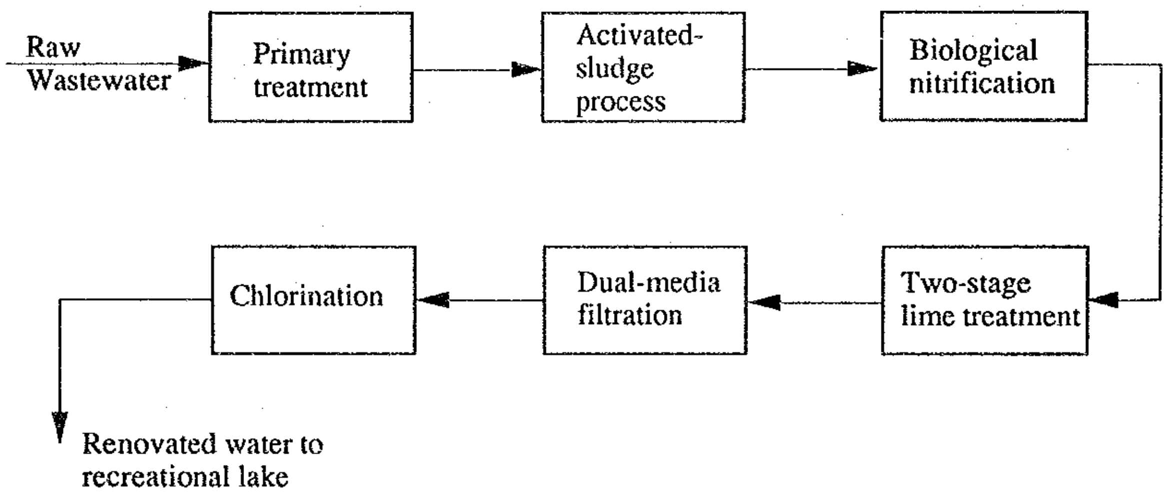

Fig. J.6 Treatment System for Producing Recreational Lake Water

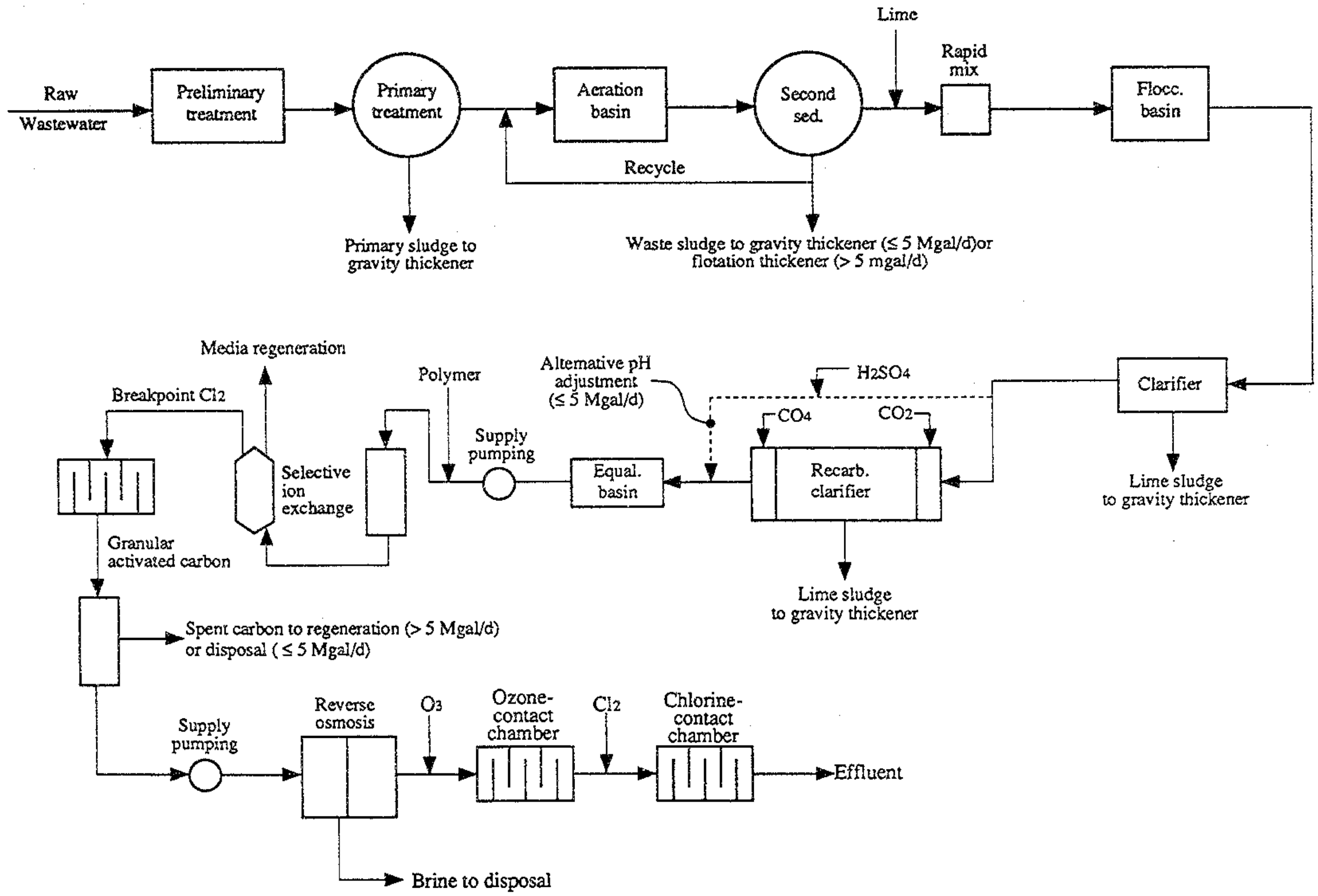

Fig. J.7 Conceptual Flow Diagram of Advanced Wastewater Treatment System Capable of Producing Potable Quality Water Supply

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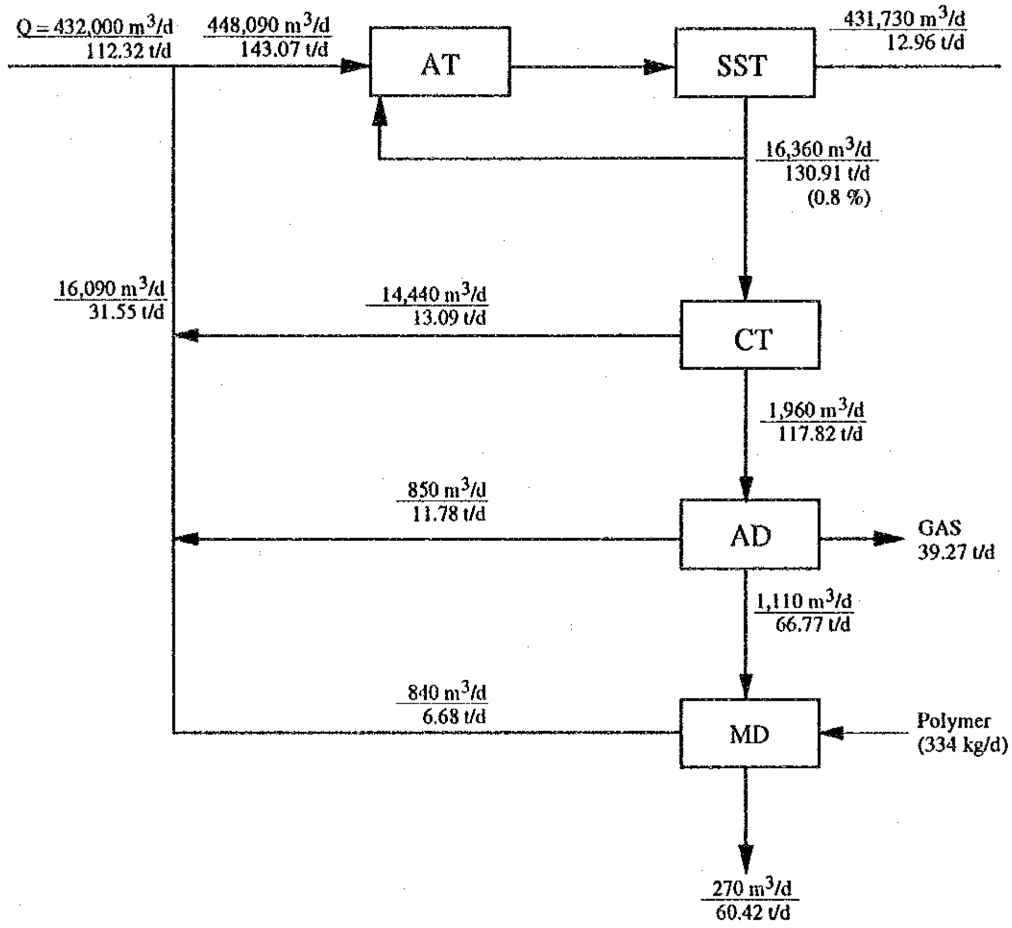
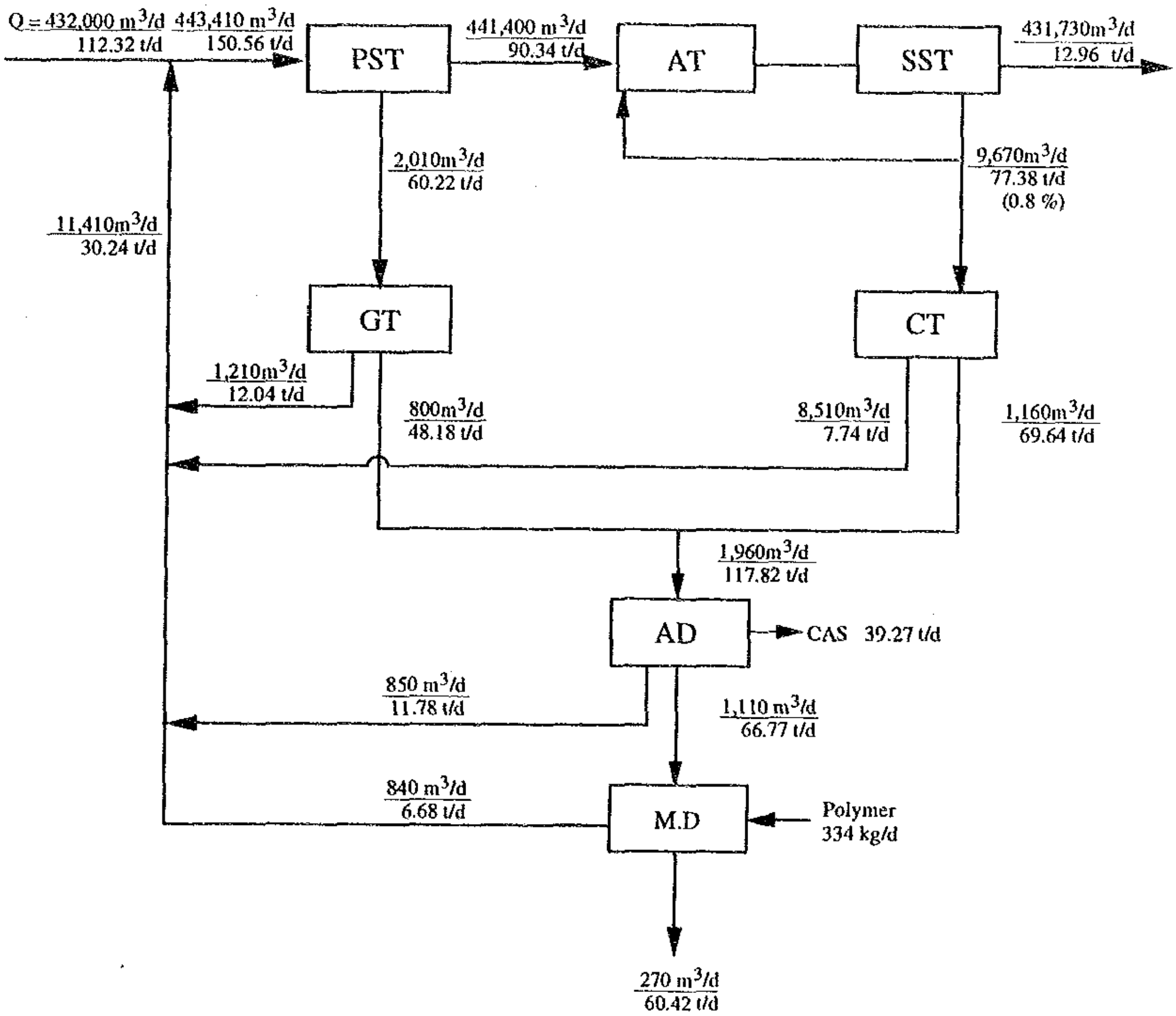


Note : 0,000 ----- Quantity of WW/sludge
00.00 ----- Dry Solid

CT : Centrifugal Thickening
AD : Anaerobic Digestion
MD : Mechanical Dewatering by Belt Filter Press

Fig. J.8 Solid Balance for the System with PST



Note : 0,000 ----- Quantity of WW/sludge
00.00 ----- Dry Solid

GT : Gravity Thickening
CT : Centrifugal Thickening
AD : Anaerobic Digestion
MD : Mechanical Dewatering by Belt Filter Press

Fig. J.9 Solid Balance for the system without PST

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