Mexico

"Monterrey Water Supply and Sewerage Project"

Project Summary

Borrower:	Mexican Government
Executing Agency:	Servicios de Aguay Drenaje de Monterrey
Exchange of Notes:	June 1992
Date of Loan Agreement:	October 1992
Final Disbursement Date:	December 1997
Loan Amount:	¥13,482 million
Loan Disbursed Amount:	¥13,482 million
Procurement Conditions:	General Untied
Loan Conditions:	Interest rate: 3.0%
	Repayment Period: 30 years (7 years for grace period)

Reference

(1) Currency: Mexico Peso (P)

(2) Exchange Rate: (IFS yearly average market rate)

Year	1992	1993	1994	1995	1996	1997
P/US$	3.1	3.1	3.4	6.4	7.6	7.9
¥/US$	126.7	111.2	102.2	94.1	108.8	121.0
¥/P	40.9	35.9	30.1	14.7	14.3	15.3
CPI*	141.7	155.5	166.3	224.5	301.7	364.0

*:CPI: 1990=100

(3) Exchange Rate at the time of appraisal: ¥/US$ = ¥137

(4) Fiscal Year: January to December

(5) Abbreviations:

CNA: Comision Nacional del Agua

SADM: Servicios de Agua y Drenaje de Monterrey

I. Project Summary and Comparison of Original Plan and Actual

1. Project Summary and ODA Loan Portion

This project aims to build a sewage treatment system which will meet the demand of 2005, and will prevent the river pollution that is due to the discharge of untreated sewage. It is an element of the Monterrey Water Supply and Sanitation Program which is intended to accommodate increasing population in the Monterrey metropolitan area in Nuevo Leon State, which is Mexico's second most important industrial city. (Refer to the third-party evaluation for a map of the project location). Within the Monterrey Water Supply and Sanitation Program the water supply improvements are financed by IDB and the sewerage improvements are financed by JBIC.

This project (the portion concerning sewerage) comprises three parts with a total project cost of ¥17,976 million (of which the local currency portion is ¥13,094 million):
① The construction of sewage treatment plants in three places
② The construction of catchment pipes
③ The construction of a pumping station
Of these, the ODA loan covered the entire construction cost of the sewerage treatment plant and the consulting cost (loan amount: ¥13,482 million).

2. Background

2.1 Population Increase in the Monterrey Metropolitan Area

The population of Monterrey and its surroundings (the Monterrey metropolitan area) was 2.5 million, approximately 80% of the population of Nuevo Leon State. The population is growing at an extraordinary rate of around 5% per year due to influx of people from surrounding areas. In 2000 the population is expected to reach 4.5 million.

2.2 Situation of the Sewerage Service

Catchment pipes cover 82% of the water supplied area, with a total of 164km of primary and secondary catchment pipes. The total length of catchment pipes is 3,378km. The collected sewage was not treated, with around 60% being used for irrigation and the remainder being mainly discharged to rivers. A very small portion was treated by the private sector and reused for industrial applications.

2.3 Necessity of the Project

The demand for clean water supply in the Monterrey metropolitan area in 2000 was anticipated at $17m^3/s$, roughly double the approximately $8.8m^3/s$ supply capacity that was available in 1990. If the supply of clean water increases but the sewage is discharged untreated to rivers, river pollution will increase dramatically and downstream water use would also be affected. Therefore countermeasures were necessary.

2.3 History

1990	December	L/A signing concerning water supply portion of this project between IDB and Mexico
		ODA loan request by Mexican Government
1991	May	Dispatch of JBIC Appraisal Mission
1992	March	Prior Notification
	June	E/N conclusion of this project
	October	L/A signing of this project

3. Comparison of Original Plan and Actual

(1) Project Scope (covered by ODA loan)

Project Scope	Planning treatment capability	Actual	Difference
① Construction of sewage treatment plant			
- Delces Nombres	5.0m^3/s	Same as left	None
- Norte	2.5m^3/s	Same as left	None
- Noreste	0.5m^3/s	Same as left	None
② Consulting service	34M/M	91M/M	+57M/M

(2) Implementation Schedule

	Plan	Actual	Difference
L/A signing	Jun. 1992	Oct. 1992	+4 months
Procuring procedures, contract	Sep. 1992 ~ Mar. 1993	Mar. 1992 ~ Nov. 1993	+8 months
Construction work of sewage treatment plant	Apr. 1993 ~ Oct. 1995	Mar. 1994 ~ Feb. 1996	+4 months
Additional work	(not initially planned)	Nov. 1994 ~ Sep. 1997	—

(3) Project Costs

Item	Plan (L/A)		Actual		Difference	
	Foreign currency	Local currency	Foreign currency	Local currency	Foreign currency	Local currency
Sewage treatment plant	4,297	7,583	4,227	8,975	-70	-1,392
(JBIC portion)	(4,297)	(7,583)	(4,227)	(8,975)	(-70)	(+1,392)
Catchment pipes	0	3,360	0	3,438	0	-192
Pumping station	36	77	0	140	-36	+63
Consultants	105	0	280	1,608	+175	+1,608
(JBIC portion)	(105)	(0)	(280)	(0)	(+175)	(0)
Land acquisition	0	151	0	982	0	+831
Total	4,438	11,441	4,507	15,143	+69	+3,702
(JBIC portion)	(4,402)	(7,583)	(4,507)	(8,975)	(+105)	(+1,392)
Contingency	444	1,653				
(JBIC portion)	(444)	(1,053)				
JBIC ODA loan amount		13,482				

Foreign currency: ¥1 million, Local currency: ¥1 million

[Exchange Rate] ¥/US$ =¥137 (at the time of appraisal)

¥126.2 (actual)

Mexico

"Monterrey Water Supply and Sewerage Project"

Shunji Matsuoka (Associate Professor, Graduate School for International Development and Cooperation, Hiroshima University)

Introduction

Between 18th and 29th April 1999 a third-party evaluation of JBIC loan project was implemented on United Mexican States "Monterrey Water Supply and Sewerage Project".

The project which was evaluated consisted mainly of the construction of three sewage treatment plants with average treatment capacities of $5.0m^3/s$, $2.5m^3/s$ and $0.5m^3/s$ with the aim of improving river water quality in Monterrey, which is Mexico's third largest metropolitan area.

Since 1970 the area has been the target of water supply and sewerage projects by the Inter-American Development Bank (IDB), and this project forms Stage I of the Fourth Water Supply and Sewerage Project (Monterrey IV).

The composition of the survey group, the survey itinerary and the main people interviewed are recorded, followed by the methodology of this evaluation and its findings.

2. Composition of the Survey Group

Group leader:	Shunji Matsuoka, Associate Professor, Graduate School for International Development and Cooperation, Hiroshima University
Group member:	Ikuho Kochi, Graduate Student, Graduate School for International Development and Cooperation, Hiroshima University

3. Survey Itinerary

1999

April 18	Departing from Kansai International Airport to Mexico City via Los Angeles
April 19	Courtesy visit to Japanese Embassy and Mexican Ministry of Finance Departing from Mexico City to Monterrey
April 20	Site Survey to Norte and Noreste Sewage Treatment Plants
April 21	Site Survey to Dulces Nombres Sewage Treatment Plant, Río Bravo Office of Comision Nacional del Agua (CNA)
April 22	Headquarters of Servicios de Agua y Drenaje de Monterrey, SADM Central Research Laboratories
April 23	Site Survey to Pesqueria River area and Cuchillo Dam
April 24	Headquarters of Servicios de Agua y Drenaje de Monterrey
April 25	Departing from Monterrey to Mexico City
April 26	Inter-American Development Bank (IDB) Mexico Office, CNA Headquarters, Official Residence of Japanese Ambassador, Summary report of evaluation results
April 27	Site Survey to Tula Irrigation Area and Mexican Environmental Research Training Center (CENICA).

April 28 Departing from Mexico City via Los Angeles

April 29 Arriving at Kansai International Airport

4. Main People Interviewed

(1) Monterrey

a) SADM：Servicios de Agua y Drenaje de Monterrey, I.P.D.
Mr. J. H. Tijerina (General Director)
Mr. L. R. Herrera (Sanitation Director)
Mr. J. A. Infante F (Finance Director)
Mr. J. M. Rendon Leal (Plant Manager)

b) Comision Nacional del Agua (CNA), Rio Bravo Office
Mr. A. A. Enderle (Regional Manager)
Mr. J. E. G. Cardenas (Technical Sub-Manager)

(2) Mexico City

a) Inter-American Development Bank (IDB), Mexico Office
Mr. F. Lari (Sector Specialist)
Mr. H. L. Castillo (Local Specialist)

b) CNA Headquarters (Finance Section)
Mr. S. A. Verduzco (Financial Manager)
Mr. M. H. Wong (Sub-Manager)
Mr. G. G. Ochoa (Hydrology Specialist)
Mr. E. P. Valadez (Sub-Manager of Financial Management)
Mr. C. D. Garza (Sub Manager of Financial Engineering)
Ms. G. M. Laguna (Chief of Financial Planning)

c) CNA Mexico Office
Mr. A. A. Sanchez (Construction Manager of Waste Water Treatment Plant)
Mr. A.L.Pevex (Director)

d) Japanese Embassy in Mexico
Katsuyuki Tanaka (Ambassador)
Masafumi Mizugami (Minister)
Satoshi Uozumi (First Secretary)

e) Mexican Ministry of Finance
Mr. S. O. Chandez (Advisor of Public Credit division)
Ms. V. P. Romero (Sub-Manager of Project Finance division)

f) National Bank for Public Works and Services (BANOBRAS)
Mr. A. A. Guerrero (Negotiator of Foreign Credit)

g) Mexico Environmental Research Training Center (CENICA)
Mr. V. J. G. Avedoy (Director)
Ikuo Gamou (Chief Advisor)
Takao Nishishita (Air Pollution Specialist)
Haruo Matsumura (Harmful Waste Specialist)
Kiyoshi Hirozumi (Coordination of Business)

5. Evaluation Subjects and Methods

This evaluation takes as its direct subjects the three sewage treatment plants covered by the ODA loan, but it will also refer to the catchment pipes, water supplies and other aspects of the wider Monterrey IV plan as necessary. First, we will explain the evaluation points used in this report.

In his large-scale work of evaluating aid projects, Cassen wrote “development aid has multiple objectives, and as such there is no single criterion for the evaluation of such projects” (Cassen 1986). Therefore, the evaluation criteria and methods vary according to the nature of the project and the viewpoint of the people conducting the evaluation, and in fact it is right that this should be the case.

For example, the World Bank focuses its evaluations on input, results, effects and impact. The evaluation points used by the Canadian aid agency, CIDA, are rationale, effectiveness, efficiency, impacts and effects (Minato, 1999).

JBIC conducts its own form of post-evaluation with aim of “learning lessons for future appraising and project management operations” (General Affairs Bureau, Administrative Supervision Office 1997). This post-evaluation uses seven evaluation points: comparison of original plan and actual for 1) project scope, 2) implementation schedule, 3) project cost, 4) project implementation scheme, 5) operations and maintenance scheme, and 6) operations and maintenance; and the project effects and impacts.

The world is moving towards standardization of evaluation points. The Working Party on Aid Evaluation was established by OECD – DAC in December 1982 and it has been discussing matters such as improvements in aid evaluation with the aim of making aid more efficient. In December 1991 the Development Co-operation Directorate of the DAC adopted a set of evaluation principles to be applied in the implementation of evaluation. The five basic evaluation points adopted were defined as relevance, effectiveness, efficiency, sustainability and impact (DAC 1991).

Relevance: Evaluation of relevance to the needs of the recipient country and the beneficiaries, and consistency with the objectives of the action.

Effectiveness: Evaluation of the degree of attainment of initial goals, or of the potential for their attainment. The factors which influence effectiveness are also evaluated.

Efficiency: Evaluation of the appropriateness of the chosen methods, time frame and expenses to the achievement of project goals.

Impact: Evaluation of all effects generated by the project (including those which are negative).

Sustainability: Evaluation of the sustainability of the project after the completion of aid.

In Japan the Ministry of Foreign Affairs and JICA base their evaluations on five points, based on the DAC evaluation principles. Following the above-mentioned international trends and the characteristics of third-party evaluation, we have adopted the above five evaluation points for use in this report. However, we have rearranged the order of the points from that used by the OECD – DAC in order to emphasize the logical analytical framework in the analysis and evaluation which follow.

First we compare the targets included in the plan on which the project was based and the degree to which they have been attained. Then we will evaluate the efficiency with which the maintenance of the sewage system is conducted. Third, we analyze sustainability to see whether or not the maintenance scheme is sustainable. Fourth, the socioeconomic and environmental impacts of sewage treatment are evaluated. Fifth, we analyze the relevance of the plan to evaluate the consistency and relevance of the plan to its targets, both originally and present.

6. Attainment Degree of Project Target

(1) Outline of the project plan

This project, which is a part of the Water Supply and Wastewater Program Stage IV (Monterrey IV) in the Monterrey metropolitan area, concerned the construction of sewage treatment plants. Monterrey IV is a new water supply plan intended to keep pace with the increase in water demand due to population growth, and it is also a sewage treatment plan. First, we will briefly explain the contents of the plan.

Figure 1 is a simplified map of the area around Monterrey. Figure 2 is a conceptual diagram of the Monterrey IV plan, and Figure 3 shows the water supply and demand plan for the Monterrey metropolitan area. According to the feasibility study (F/S) of the project, at the time of project formation (1990), the population of Monterrey metropolitan area plan was 2.52 million and was expected to rise to 3.5~4.1 million people by 2000. To keep up with this prediction of extremely rapid population growth, the plan was adopted in 1993 to build the Cuchillo Dam and install conduit pipes from there to increase the water supply capacity from $9.5m^3/s$ in 1990 to $14.5m^3/s$ in 1997. In order to proceed with this water resource development plan, two problems had to be solved: conservation of the water quality in the catchment area of the Cuchillo Dam that would serve as the water source, and a stable (treated) water supply to supply to Tamaulipas State, holder of downstream water rights.

To this end, Monterrey IV planned to expand the catchment pipe network and divert all the sewage that was previously discharged to the Santa Catalina River to the Pesqueria River. Sewage treatment plants, including secondary treatment, were to be constructed at that stage to treat the water to a quality of 30mg/l BOD to meet regulation values for river discharge.

The sewerage project program drawn up to meet this target comprised the following three projects:

① The construction of three sewage treatment plants with average treatment capacities of $5.0m^3/s$ (the Dulces Nombres Sewage Treatment Plant), $2.5m^3/s$ (Norte Sewage Treatment Plant) and $0.5m^3/s$ (Noreste Sewage Treatment Plant) to discharge into the Pesqueria River, which flows from the east to the west in the northern part of the metropolitan area. This treatment would prevent the flow of pollution into the Santa Catalina River, which is an upstream water source (it flows into the Cuchillo Dam).

② The laying of an additional 130km of catchment pipes in addition to the existing catchment pipes and bring all sewage to the three sewage treatment plants.

③ The construction of a pumping station with a capacity of $0.7m^3/s$ to pump sewage from the Santa Catalina River in the south to the Dulces Nombres Sewage Treatment Plant in the north.

Of these three, the ODA loan covered the construction of the sewage treatment plants for part ①.

(2) Project Targets

In order to evaluate this project's effectiveness in reaching its targets, we must clarify what the targets were, which we will do using the survey and project-related documents.

According to JBIC documents prepared at the time of the appraisal, the aim of the project was to build a sewerage system which will meet the demand of 2005 as an element of the Monterrey Water Supply and Sewerage Project (Monterrey IV), which is itself intended to build water supply and sewerage systems to cope with population increase in the Monterrey metropolitan area. The sewerage system would prevent river pollution which then occurred due to the discharge of untreated sewage, and accommodate the use of river water downstream.

The size of the sites for the sewage treatment plants were to be adequate for requirements in 2005, the target year for the project. The capacity for sewage treatment was determined from the water supply plan. It was calculated that the current water supply capacity was $9.5m^3/s$ and the increase between 1993 and 1997 would be $5.0m^3/s$ for a total supply capacity of $14.5m^3/s$, which would generate waste water at a rate of $8.0m^3/s$. Therefore the overall sewage treatment capacity was set at $8.0m^3/s$ to meet the 1997 level of demand.

In other documents, such as the F/S, the plan is divided into two stages, as shown in Table 1, with Stage I beginning in 1993 and Stage II in 1996. Under that approach, Stage I would be completed in 1995. The Servicios de Agua y Drenaje de Monterrey (SADM), which is the executing agency, initially planned a three-phase sewage system project, as shown in Table 2.

Under that plan, Phase 1 would be finished in 1999.

Based on documents prepared at the time of the appraisal, we take 2005 to be the final target year for the project, with the project target being that all treatment plants should have work rates of 100% by 1997.

According to documents prepared at the time of the appraisal, the targets for water quality were set as shown in Table 3. These target values were set according to sample surveys taken at ten locations over one week in October 1989 (end of rainy season) and one week in June 1990 (start of rainy season). They also took into account the water quality standards for the river, the intended uses of the river water and other considerations. Values were set for nine water quality indicators, including 30mg/l BOD. The other main indicators were 30mg/l TSS, 2mg/l N-NH3 (ammonia nitrogen) and 1000/100ml fecal coliform count. In 1996 Mexico's standard values for water discharges were greatly relaxed and the BOD standard value was eased from 30mg/l to 150mg/l.

In order to reach the above quantitative and qualitative targets, this project was to include the construction of three sewage treatment plants with a combined treatment capacity of $8.0m^3/s$, and the construction period was to be from April 1993 to October 1995. The amount of the loan was put at ¥13.482 billion.

The results of the project were that the three sewage treatment plants with a combined treatment capacity of $8.0m^3/s$ were built at the scale and cost planned with some delays. Although the start of construction was delayed until March 1994, the Norte ($2.5m^3/s$) and Noreste ($0.5m^3/s$) Water Treatment Plants were completed ahead of schedule by July 1995 and May 1995 respectively. Only the largest plant, the Dulces Nombres Sewage Treatment Plant ($5.0m^3/s$) was delayed by four months to February 1996 by Mexico's economic crisis, bad weather and other factors, but the impact of this delay on the project as a whole appears to have been slight.

(3) Target Attainment Degree

We will examine the effectiveness of this project in both qualitative and quantitative terms. Figure 4 shows movements in average treatment volume for each sewage treatment plant. The average for 1997, which was the target year, was $5.548m^3/s$, 69.4% work rate relative to the planned capacity of $8.0m^3/s$. Looking at each plant individually, the treatment volume at the Dulces Nombres Sewage Treatment Plant was $3.423m^3/s$, 68.5% of the planned $5.0m^3/s$, at the Norte Sewage Treatment Plant the treatment volume was $1.523m^3/s$, 60.9% of the planned $2.5m^3/s$, and at the Noreste Sewage Treatment Plant, the smallest of the three, treatment volume was $0.602m^3/s$, 120.4% of the planned $0.5m^3/s$.

Sewage treatment plants in Japan are designed for peak daily treatment capacity, but those in Monterrey are designed for average treatment capacity. The $0.5m^3/s$ treatment capacity of the

Noreste Sewage Treatment Plant is an average treatment capacity[1]. It is impossible to make a simple comparison because the design standards differ, but the maximum daily treatment capacity at the Noreste Sewage Treatment Plant is 0.75m^3/s.

Therefore, the plant can treat a volume of 0.75m^3/s throughout the day but, as Figure 5 showed, it exceeds that capacity for around 17 hours in each day (20th April 1999), and as Table 4 showed, on the 1997 average it was overflowing by 0.112m^3/s. The overflow volume passes through debris removal and sedimentation, but the primary and secondary treatments are omitted before it is chlorinated and discharged to the river, which damages water quality.

The SADM attributes the overflow to influx of groundwater due to defective laying of sewer pipes. They plan to counter the problem by inserting vinyl (or polyethylene) pipe inside the existing sewer pipes. They are also considering linking the catchment pipe network that leads to the Noreste Sewage Treatment Plant and that leads to the Dulces Nombres Sewage Treatment Plant. (They are now two separate systems.) In any case, within a system running at a work rate of less than 70% overall, there is an overflow at the Noreste Sewage Treatment Plant. While the volume is small compared to the capacity in the whole system, untreated water was being discharged to the river in 1998 and the situation was still continuing at the time of the survey in April 1998.

As the above situation clearly demonstrates, when the attainment of targets for the volume of sewage treated is evaluated in terms of the work rate, it is not enough to say that the project is effective if the work rate is at 100% or more. Instead, it is more important to consider whether the treatment plant is working effectively and delivering the initially planned water quality. The work rate of 70% is not bad compared to figures for sewage treatment plants in Japan and appears to be within the range which can be considered effective usage of the facilities. Furthermore, the main reason why the volume did not reach the initially planned figures is that there has been a water shortage since the start of the '90s (see Table 5). The average rainfall in the region has dropped severely since the start of the '90s and even the Cuchillo Dam, which was built as a new source of water supply, is unable to hold an adequate volume of water. Therefore, the supply of water from the dam has dropped to 3.5m^3/s instead of the planned 5.0m^3/s. The water saving campaign by the SADM, which is the water supply agency, is successful, cutting per capita daily consumption from 350 l at the time of the plan to around 250 l. The population with sewerage services was largely as planned at 2,956,000 in 1997, but the total volume of sewage generated in the Monterrey metropolitan area has fallen far below the initial prediction.

We will now examine water quality. Table 6 shows the quality of treated water at each treatment plant. The only point in the quality target that was not reached in 1997 was Ammonia Nitrogen

[1] Peak daily treatment capacity is the treatment capacity of a sewage treatment facility determined according to the maximum sewage volume per day through one year. Sewage treatment plants in Japan are now designed for this value. The daily average treatment capacity is the treatment capacity of a sewage treatment facility determined according to the daily average volume derived from the total volume of sewage treated in one year. In general it is 70~80% of the peak daily processing capacity (Sato 1980).

(N-NH3) at the Norte Sewage Treatment Plant. All other targets were reached. (However, in 1998, the N-NH3 level in water treated at the Noreste Sewage Treatment Plant was 3.6mg/l compared to the standard value of 2.0mg/l). The reasons for the Norte Sewage Treatment Plant alone failing to reach the target appear to be a problem with the inflowing water and a problem with the treatment method. It is normally difficult to remove N-NH3 in secondary treatment, and the concentration in the water flowing into the Norte Sewage Treatment Plant is 68mg/l, a high concentration equal to that at raw human waste treatment facilities in Japan. The reason for the high concentration is very likely to be the industrial waste that accounts for around 40% of the inflow volume. For example, the effluent from factories that use ammonia nitrogen as raw material (fertilizer manufacturing factories etc.) are a likely culprit. Regulation of such effluent is needed. The treatment method is the pure oxygen method at the Dulces Nombres Sewage Treatment Plant, and the long-term aeration method at the Noreste Sewage Treatment Plant. These methods provide adequate air exposure to oxidize the ammonia nitrogen to form nitrogen nitrate (NO_3-N and NO_2-N). The Norte Sewage Treatment Plant uses the standard activated sludge method with a relatively low level of aeration, resulting in a low proportion of oxidization, and ammonia nitrogen is discharged at a high concentration. One countermeasure would be to raise the mixed liquid average suspended solids (MLSS) level in the aeration tank and mix it with a large amount of air. The problem with that method is the cost of electricity for the necessary air blowing. Cost effectiveness will have to be considered carefully.

In summation, this project has been generally highly effective in achieving its water volume and water quality targets and it can be deemed to have achieved those targets.

7. Maintenance Situation at the Sewage Treatment Plant and their Efficiency

In this section we will analyze the maintenance situation at the three sewage treatment plants and evaluate whether each is functioning effectively with regard to its efficiency.

(1) Outline of the Three Sewage Treatment Plants

We will clarify the key points of the sewage treatment plants before comparing them to sewage treatment plants in Japan to illustrate their characteristics[2].

Table 7 summarizes Monterrey's sewage treatment plants. Figure 6 shows their relationship to Japanese plants in large urban areas with reference to planned population and treatment capacity. As mentioned above, the design standard for treatment plants in Japan is based on peak daily

[2] In the following analysis we plot a reference line based on water treatment data for major Japanese cities. This analytical method deserves some further explanation. (1) This analysis compares sewage treatment plants as far as their secondary treatment stages based on common points in their technical characteristics. The differences between a developed country (Japan) and a developing country (Mexico) do not limit this kind of analysis. (2) The data used on Japanese large cities and their sewage treatment plants were from around 1990. For the analytical method used here, which considers the technical characteristics of the active sludge method, this ten year gap does not impair the analytical content or the reliability of the results.

treatment capacity, but those in Monterrey are designed for average treatment capacity. Therefore, to compare the two groups on an equal footing, we have taken the peak treatment capacity for the Monterrey plants. The figure shows that the designed treatment capacity per capita of the planned population is lower than the regression line for Japan, and the base unit (the maximum sewage discharge volume per capita per day) is set rather lower than it is in Japan. In terms of the scale of the plants, the Dulces Nombres Sewage Treatment Plant is relatively large, the Norte Sewage Treatment Plant is average and the Noreste Sewage Treatment Plant is small compared to Japanese sewage treatment plants.

The five treatment methods considered at the time of the F/S were the standard active sludge method, the long-term aeration method (active sludge method), the filtration method and two types of aeration lagoon method. Nine indices were set for the comparison: efficiency, flexibility, experience, land conditions, energy conditions, sludge treatment, water quality, climatic conditions and labor input. Each index was given a weighting and used in Multi-Criteria Analysis (MCA). The cost effectiveness analysis, which compared the points gained against the cost, found that the long-term aeration method would be the best option for all sewage treatment plants.

However, the treatment method was changed at a later stage, and the three plants were tendered for individually, on a turn-key lump sum basis. The tenders were for the design of the treatment method, the construction of the treatment plants, and their operation for the first three years after completion. The result, as shown in Table 7, was that the Dulces Nombres Sewage Treatment Plant used the active sludge method, with the pure oxygenation method, a method not often seen in Japan.

The pure oxygen method is intended to increase the BOD volume load in the aeration tank and make treatment more economical by using pure oxygen instead of air. This method is able to maintain dissolved oxygen (DO) in the tank at a high level, which keeps the micro-organisms highly active. Their increased activity shortens the aeration time and reduces the size of aeration tank required. It also generates less surplus sludge, improves sludge precipitation and is able to handle sewage of high BOD levels. There is less secondary harm in the form of noise and odor, making the pure oxygen method convenient to use. The drawbacks to beware of are strong pH reduction due to the generation of large amounts of CO_2, and the buildup of hydrocarbons (Sato, 1980).

The Norte Sewage Treatment Plant uses the standard active sludge method which is common in Japan.

The Noreste Sewage Treatment Plant uses the long-term aeration method, which greatly reduces the volume of surplus sludge and makes maintenance easier. Exposure to air over a very long period causes the sludge to break down spontaneously, reducing the amount of sludge left for disposal (Sato, 1980). Under this method, sludge precipitation proceeds poorly and it can be washed out in the discharged water, degrading the quality of the treated water. It is relatively resilient against variations in load, but the aeration tank is large and the running cost is high, which is why this method is only used for small-scale treatment plants (Moba, 1985).

(2) Efficiency of Maintenance

We will now evaluate the efficiency of the three constructed sewage treatment plants with a view to their effective use. As we have discussed work rates in the previous section, we will now evaluate the efficiency of the maintenance of each treatment plant in terms of its costs and labor input. We will also look at the adoption of different processing methods for each plant, despite the plans at the F/S and appraising stages that called for all to use the same treatment method. In addition, we will evaluate whether the buildings (floor area) are being used effectively.

First, we will compare the three treatment plants. Table 8 showed the numbers of workers, maintenance costs and other factors per unit of treatment capacity for each of the three plants in 1998. The table shows that worker numbers and treatment costs per unit capacity are lowest at Dulces Nombres Sewage Treatment Plant. However, the economies of scale are substantial for a plant of this scale and that effect must be taken into account in the comparison. Therefore we will examine its position relative to a sewage treatment plant in a large Japanese city.

Figure 7 showed the number of workers relative to the treatment volume. The regression line is for a Japanese sewage treatment plant. Taking that as the reference line, both the Dulces Nombres and Norte Sewage Treatment Plants used relatively large numbers of workers, but the Noreste Sewage Treatment Plant used fewer workers. This result reflects the use of the long-term aeration method, which requires fewer workers for maintenance, at the Noreste Sewage Treatment Plant.

Figure 8 shows the treatment cost against treatment volume. This is only a guideline due to the differences in exchange rates between the Peso and the Yen and their purchasing power parity, but the Noreste and Norte Sewage Treatment Plants are below the regression line, while the Dulces Nombres Sewage Treatment Plant is on the line. This suggests that the cost effectiveness of the Dulces Nombres Sewage Treatment Plant is lower than that of the other two plants.

The differences in work rates at each plant must also be considered here, but the difference in cost effectiveness appears to be largely due to differences in treatment methods. As noted earlier, the findings of the F/S and the appraisal indicated that long-term aeration would be the optimum method in terms of cost effectiveness, but in the end, only the Noreste Sewage Treatment Plant used that method. Feasibility studies are not always correct, but for the sake the continuity of the project cycle, in the form of consistency between the project formation stage (F/S) and the project implementation stage, it is important to consider why the conclusions of the F/S were changed and whether or not the alteration was a wise one. Generally speaking, it is not desirable for three sewage treatment plants to use different treatment methods because the use of one consistent method is better for the accumulation and pooling of experience and skills within an organization. In fact, Director Romero, Sewerage Office, SADM expressed that concern to the survey group. It is a point that must be considered in the implementation of future projects of this type.

The use of the buildings (floor area), and its efficacy, changed from that planned at the time of the bidding. SADM has now taken sole control of the maintenance of the three sewage treatment plants, rendering the rooms in each plant that were used for management operation and water quality testing obsolete. These unused areas amount to $80m^2$ each at the Dulces Nombres and Noreste Sewage Treatment Plants and $150m^2$ at the Norte Sewage Treatment Plant. This problem is related to the way the bidding was handled, which should be reconsidered. SADM is now considering using the spare space for researchers from local universities or for environmental education.

While there were some problems in the selection of treatment methods, the actual maintenance costs overall are lower than anticipated at the planning stage (see Table 9) and there are no major problems with efficiency.

8. Operations and Maintenance Scheme and Its Sustainability

In this section we will evaluate the operations and maintenance scheme with a view to its sustainability.

(1) Summary of Operations and Maintenance Scheme

Documents from the time of the JBIC appraisal show that under the anticipated operations and maintenance scheme "operation and maintenance after the completion of the project shall be handled by SADM's operation department", giving SADM sole and direct management jurisdiction. After that, in the project implementation stage, a contract form was adopted that included design, construction, operation and maintenance for three years, with separate contracts for each plant. As a result, different treatment methods were chosen for each plant, and each one was operated by a different contractor. At the time the contracts were signed and at the start of plant operation, it was expected that the plants operation would continue to be contracted out to the private sector under the supervision of SADM after the three years term expired.

However, as SADM gradually built up its expertise in sewerage management, it began to notice that the operation and maintenance carried out by the contractors was not necessarily highly efficient. For example, when buying chemical agents such as chlorine and polymer, the contractors often bought at high prices without going through sufficient competitive bidding. Therefore, when the initial three year period expired at the end of 1998 and the start of 1999 (the contract start times differed between the plants) SADM took the opportunity to move into unified authority over operation and maintenance for all three plants. With this change, 16 operation staff from the Dulces Nombres Sewage Treatment Plant, 18 from the Norte Sewage

Treatment Plant and seven from the Noreste Sewage Treatment Plant moved from the various contractors to SADM. These transferred staff amounted to 21% of the total operation staff and made a large contribution to strengthening SADM's organization.

(2) SADM

According to documents prepared at the time of the JBIC appraisal, SADM is said to have a charge collection rate of over 90%, which makes it the kind of powerful water and sewerage company that is unusual in developing countries. Table 10 shows the history of SADM. It was established in 1906 as a subsidiary of a company based in Toronto, Canada. In 1945 Nuevo Leon State government bought the subsidiary and placed its management in the hands of Monterrey Commercial Bank. In 1956 a state law established it as Servicios de Agua y Drenaje de Monterrey, which has been its title until now. In 1995 the administrative area in which SADM is allowed to provide water supply and sewerage services was expanded from the Monterrey metropolitan area to the whole State of Nuevo Leon.

In Mexico City, the capital, water supply and sewerage services are divided between around 20 operators, which makes SADM's position of the single organization for the whole of Nuevo Leon State remarkable. The background to this situation is partly historical, but another factor is that the Monterrey metropolitan area is an industrial zone with high income, and the price which is acceptable (WTP) for water as a commodity is relatively high. In any case, the sustainability of a project largely depends on the managerial ability of the executing agency. When aid is provided in the future it is important to consider how the formation of organizations such as the SADM can be supported.

The number of sewerage service contracts with SADM has grown steadily from 468,941 (around 2.27 million people) at the time of the plan (1990) to 656,656 contracts (around 3.08 million people) in 1998, covering 97.21% of the target population. The water charge collection rate has remained at high level. SADM is taking business initiatives to sell treated water to factories as coolant and to levy extra charges for treatment of industrial waste water that exceeds standards. These are signs of a high level of managerial ability in the executing agency, which indicates a very high level of sustainability for this project.

9. Impact by Project Implementation

Based on the above evaluation and analysis of effectiveness, efficiency and sustainability, it is reasonable to say that this project has achieved an extremely high level of performance. These three indicators are used to evaluate the internal aspects of the project. Next, we will evaluate the impact of the project, which means the external effects of the project's implementation, which are socioeconomic and environmental.

(1) Classification of Impacts

Figure 11 shows the matrix used for analysis of the impacts of this project. The anticipated impacts of the project were those anticipated at the time of the appraisal, namely the prevention of river pollution and a contribution to downstream water usage. The unanticipated impacts included some that were desirable (positive impacts) and some that were not (negative impacts). The positive impact was that the SADM's ability increased to a level where it was able to take sole charge of the management of the sewage treatment plants. The unanticipated negative impact was that the discharge of all treated water to the Pesqueria River produced an increase in irrigation water in that river basin and aggravated water conflicts. As noted earlier, this situation was produced by the unusual drought of the 1990s, and the fact that rights to the water are held by Tamaulipas State downstream.

(2) Evaluation of Impacts

First, we will analyze the improvement in water quality that was the anticipated effect of this project. As stated previously, this project discharges all treated water to the Pesqueria River, which flows through the north of the Monterrey capital area. This prevented the discharge of sewage to the Santa Catalina River and the other rivers flowing through the metropolitan area, which would save the lower reaches of those urban rivers from pollution even if the water would not have been treated.

We will now concentrate on the Pesqueria River, which receives the discharge of treated water. This survey was conducted in the dry season, when all the rivers in the Monterrey metropolitan area other than the Pesqueria were almost completely dry apart from a few groundwater springs. All the water in the Pesqueria was treated sewage water, which means the water quality of the river depends on the quality of the treated water. Figures 9, 10 and 11 shows BOD, SS and fecal coliform counts measured in the Pesqueria River between 1994 and 1998 (SS was also measured in 1997).

The measuring point located at Escobedo, which is downstream from the Norte Sewage Treatment Plant, has recorded remarkable improvements in all indicators since the plant began working in 1996. Suspended solids (SS) fell by 63.2% from 462mg/l in 1995 to 170mg/l. BOD dropped by 91.8% from 281mg/l to 23mg/l. Fecal coliform count fell 50,825,000NMP/100ml in 1996 to 3,540NMP/100ml, a reduction of 99.99%.

The figures for the measurement point at La Arena, which is downstream of all the outfalls (the outfalls of the three sewage treatment plants) demonstrate the efficacy of the Noreste plant, which started operation in July 1995. SS was reduced by 91.6% from 226mg/l in 1994 to 19mg/l in 1995 and fecal coliform count was reduced by 91.9% from 26,956,667 NMP/100ml to 1,370,000 NMP/100ml. From these results we can judge that this project has had an extremely large impact on the quality of water in the Pesqueria River.

However, at Los Herrera measurement point that is approximately 65km downstream from

Arena, BOD changed little between 1994 and 1998 and the fecal coliform count actually rose in 1996. No effect from the project could be observed. Between 1995 and 1997, SS at Los Herrera rose continuously, which appears to be largely due to the reduction in flow volume caused by the drought[3]. Thus the beneficial impact of the project in improving water quality was confined to the vicinity of the metropolitan area.

We will now turn to evaluation of the second anticipated impact: "contribution to downstream water usage". First we must clarify the actual area referred to as "downstream". As mentioned earlier, the main water usage rights over the rivers which flow through the area are held by the farmers of Tamaulipas State, which lies downstream of Nuevo Leon State. Therefore when the Cuchillo Dam was built, an agreement was reached between the two states under which SADM was obliged to discharge at least $6m^3/s$ of treated water into the Pesqueria River in return for the water drawn from the Cuchillo Dam.

Accordingly, the water belongs to the farmers of Tamaulipas and the "downstream" envisaged in this project is Tamaulipas State.

The positive impact of this project on water usage downstream, and particularly on usage in Tamaulipas State, cannot be confirmed due to the large change in external conditions, namely the drought. In recent years the volume of rainfall in the region has been declining, reducing the volume flowing in the rivers. In addition, the farmers of the Pesqueria River basin, seeing the treated water flowing in front of them, have been increasing the amounts of water they draw from the river. The result is that water reaches to the farmers of Tamaulipas is limited. (SADM is also unable to draw the planned volume of water, and the volume of their water discharge from the treatment plants does not reach $6m^3/s$). This situation is aggravating the water disputes between upstream and downstream areas and disturbing order in the river basin.

Thus the impacts of this project can be evaluated as follows: Water quality in the urban rivers and in the Pesqueria River near the outfalls has improved dramatically, a confirmed positive impact. On the other hand, the intended beneficiaries, the farmers of Tamaulipas State, are largely unaffected by the sewage water quality in the Monterrey metropolitan area, and the water quality improvement yielded by this project had no noticeable impact on them. Furthermore, the discharge of treated water to the Pesqueria River was observed to have the negative impact of disturbing the established water usage situation along the course of the river.

10. Relevance of the Project

Finally, we will analyze the relevance of the project with reference to three points, its necessity, its consistency and its appropriateness. The necessity criteria which are used in evaluation of the relevance of the project are the strength and scale of the social need for the project. The criteria for consistency, which are used to consider if there is consistency in the results and impacts of

[3] An oil refinery operated by PEMEX, the Mexican petroleum corporation, discharges water into the river, slightly upstream of the Los Herrera measurement point, which is likely to influence the readings.

the project, are whether or not the aims of the project are significant at the time of evaluation and whether or not the results of the project are consistent with overall targets. The appropriateness of the project is used as a criterion for examining the order of priority of projects in developing countries. These three aspects of relevance are evaluated in order below.

(1) Necessity of the Project

On the necessity of this project, the documents prepared at the time of the JBIC appraisal stated "If the supply of water supply increases but the sewage is discharged untreated to rivers, river pollution will increase dramatically and downstream water use would also be affected. Therefore countermeasures are necessary".

As stated before, the regulatory standards for water discharges were drastically relaxed in 1996, including raising the BOD standard volume from 30mg/l to 150mg/l. This is the result of legislation moving to meet the reality of slow progress in the construction of sewage treatment plants. In Mexico today, there is less need for secondary treatment in sewage treatment plants. In Mexico City, most sewage is still discharged without treatment and the biggest task for the time being is to provide primary treatment.

Nevertheless, the issue of how necessary it was to include secondary treatment in sewage treatment plants in the Monterrey metropolitan area should be debated within the broader framework of a consistent sewage treatment policy, rather than solely in relation to regulatory standards set by Mexico at any given time. From that point of view, the current regulations can be viewed as an excessive moratorium on construction, and the treatment facilities at Monterrey, which aimed to reach levels seen internationally as desirable, can be provisionally evaluated as an appropriate level of facilities and not an excessive one.

(2) Consistency of the Project

As described in the previous section, the relaxation of water quality standards means that the targets set for the project based on the previous standards are not necessarily valid under the current situation. Furthermore, as the impact analysis of downstream water supply showed, the project is not fully functioning and is rather creating confusion, although the situation is largely due to climate change, an external factor.

(3) Appropriateness to Mexico

The Ministry of Foreign Affairs ODA White Paper of 1995 indicated the importance of a differentiated approach, one that tailors aid to the level of development in developing countries. The white paper sets Mexico as an aid recipient nation where "considering the potential for the application of private-sector funds, ODA loans should be channeled to tasks such as the correction of regional disparities and conservation of the environment where it will address the problems that arise in the course of economic development, and technological cooperation should be used to transfer advanced technologies". (Ministry of Foreign Affairs, Economic Cooperation Office 1995, p.53).

From that point of view, this project, which built sewage treatment plants with the aim of conserving the environment, can be judged to be an appropriate project for Mexico. In addition, the ability of the executing agency, the counterpart in the ODA loan project, is a decisive factor for the efficient and effective implementation of ODA loans. Therefore, it is good that the presence of SADM as a water supply and sewerage company with a level of managerial ability outstanding in Mexico raised the priority of the Monterrey metropolitan area.

11. Conclusion

This project earns high marks on three points: effectiveness, efficiency and sustainability. As for the relevance of the project, it can be described as an appropriate environmental project for Mexico. However, the impact by the project implementation had both positive and negative aspects.

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13. Collected Material

(1) SADM

Contractor vs. Table of comparison for SADM maintenance cost, Site map (outsize), Research center brochure, Financial report, Sewerage treatment flux (1998, 1999), Water quality of sewerage treatment (BOD, SS, N-NH3) (1998, 1999), Water quality of sewerage treatment (colon bacilli) (1996-1999), Maintenance cost (1998-1999), Maintenance budget (1999), Organization chart of sewerage treatment plant, Norma 001, 002, 003, Sewerage treatment plant capability, Clean water and sewerage service supply population (1998), Population increase of Noreste connecting area (partial), Graph on changes of days for Noreste treatment flux (1999), Photos on sewerage and drainage situation before project implementation (3 photos), Treatment plant brochure

(2) CNA Monterrey Office: Briefing Material on 21st April

(3) CNA Headquarters: CNA Annual Report 1997, CNA Organization Chart (1 sheet)

(4) IDB Mexico Office: Evaluation Report (Draft) at the time of completion of Monterrey IV

(5) CENICA: 6 documents

Figure 1 Peripheral Map for Monterrey Water Supply and Sewerage Project

Legend

Existing headrace channels

Headrace channels under construction

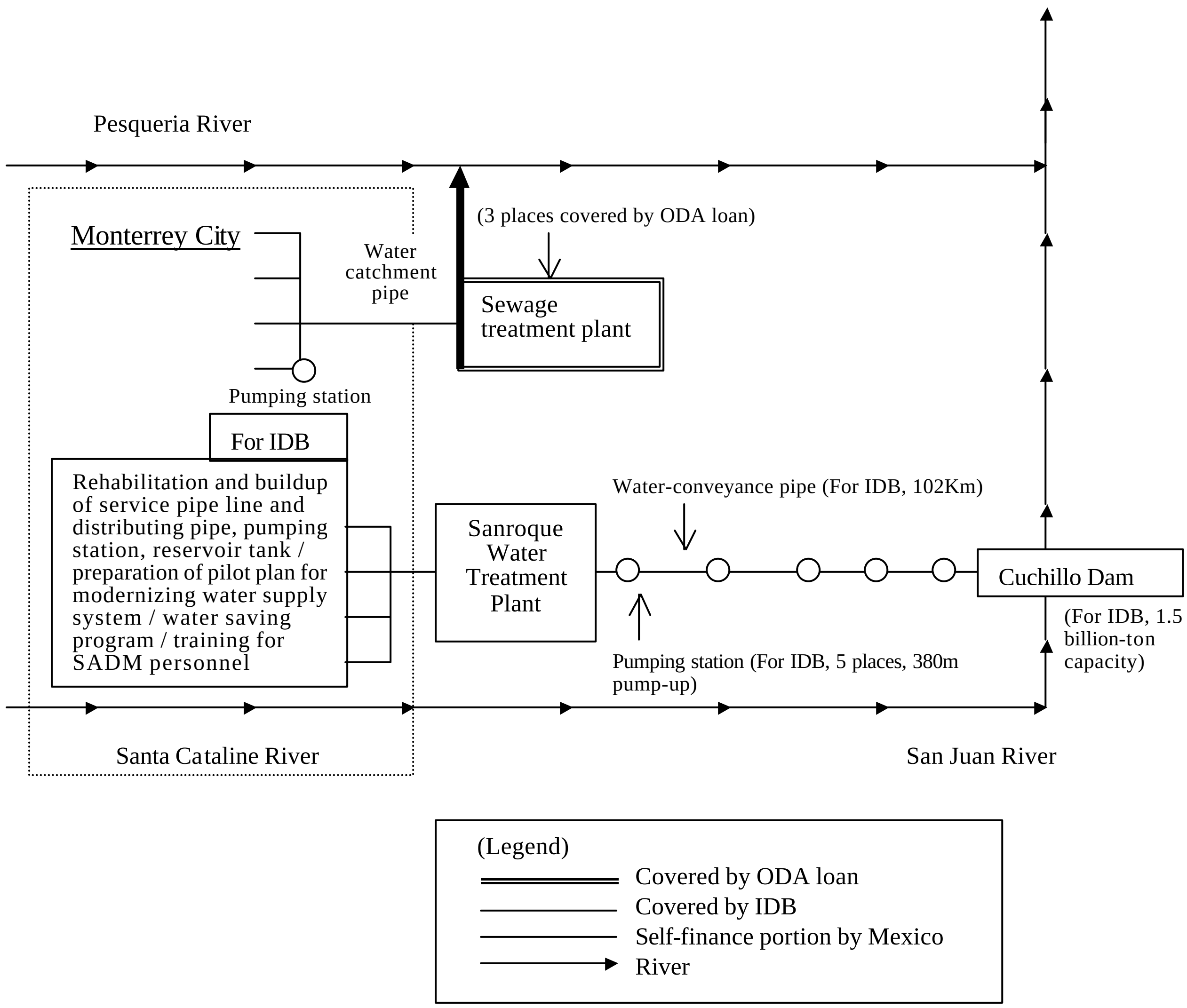
Irrigated area

(Source) Prepared from the JBIC materials.

Nuevo Leon State

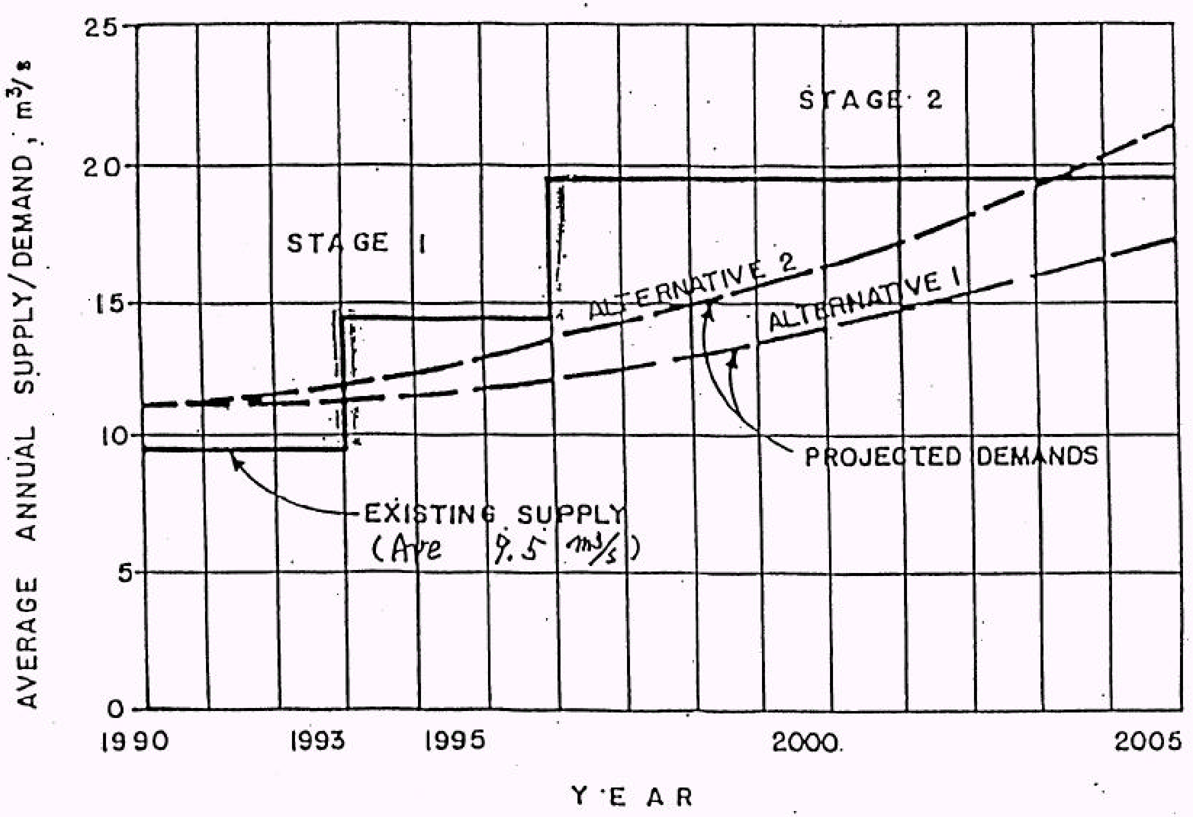
Tamaulipas State

Figure 2 Conceptional Diagram for Monterrey Water Supply and Sewerage Project (Monterrey IV)



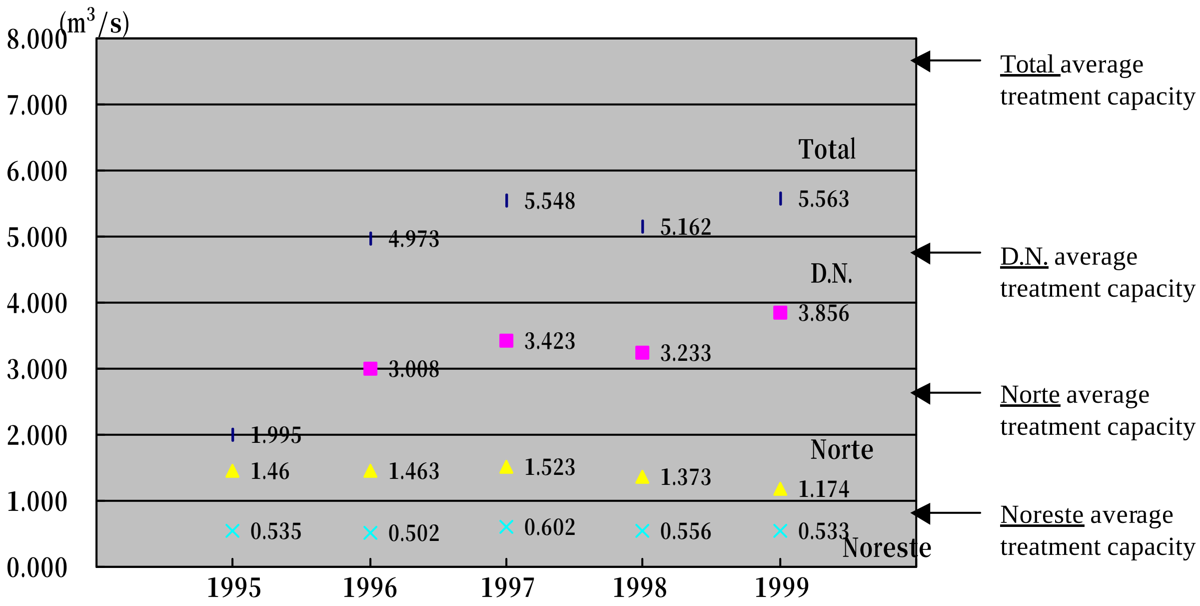
(Source) JBIC

Figure 3 Water Supply and Demand Program in Monterrey City Area



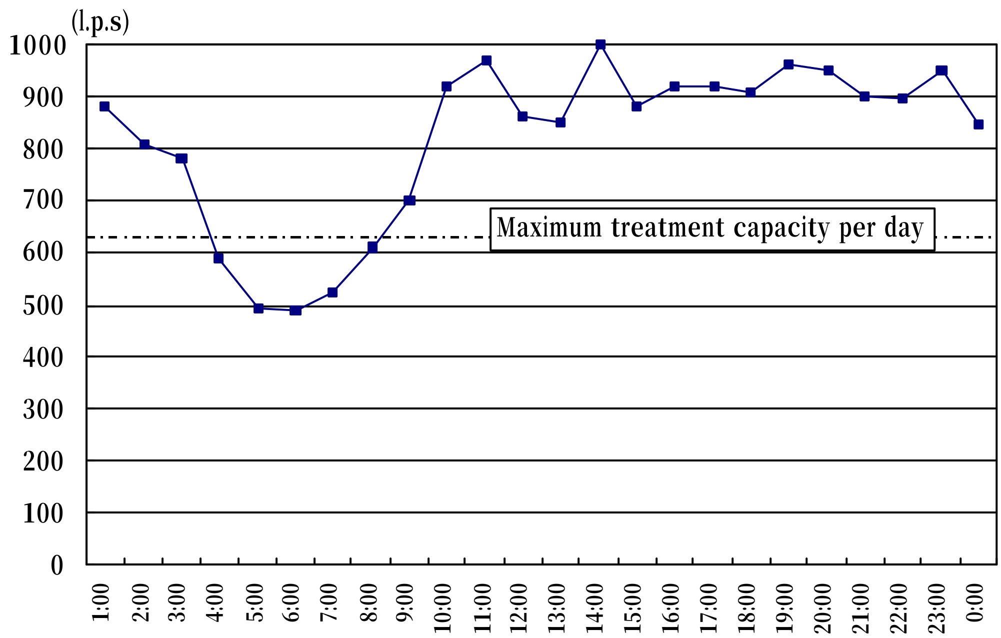
(Source) JBIC

Figure 4 Transition of Annual Average Treatment Volume at Monterrey Sewage Treatment Plant



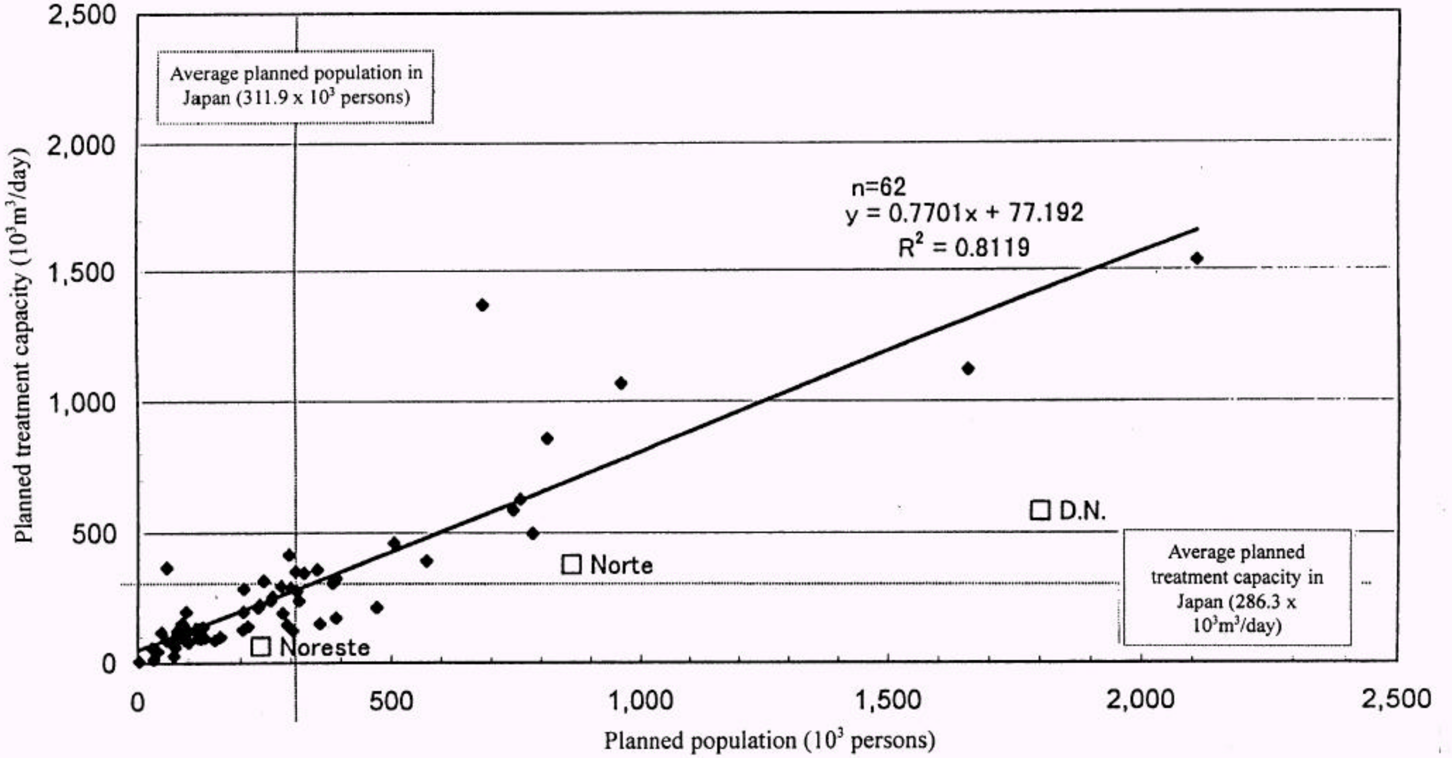
(Source) Prepared from SADM (1998) and SADM materials.

Figure 5 Changes of Discharge in Noreste Treatment Plant (April 20, 1999)



(Source) Prepared from SADM materials.

Figure 6 Planned Population and Planned Treatment Capacity of Sewage Treatment Plants in Monterrey and Japan

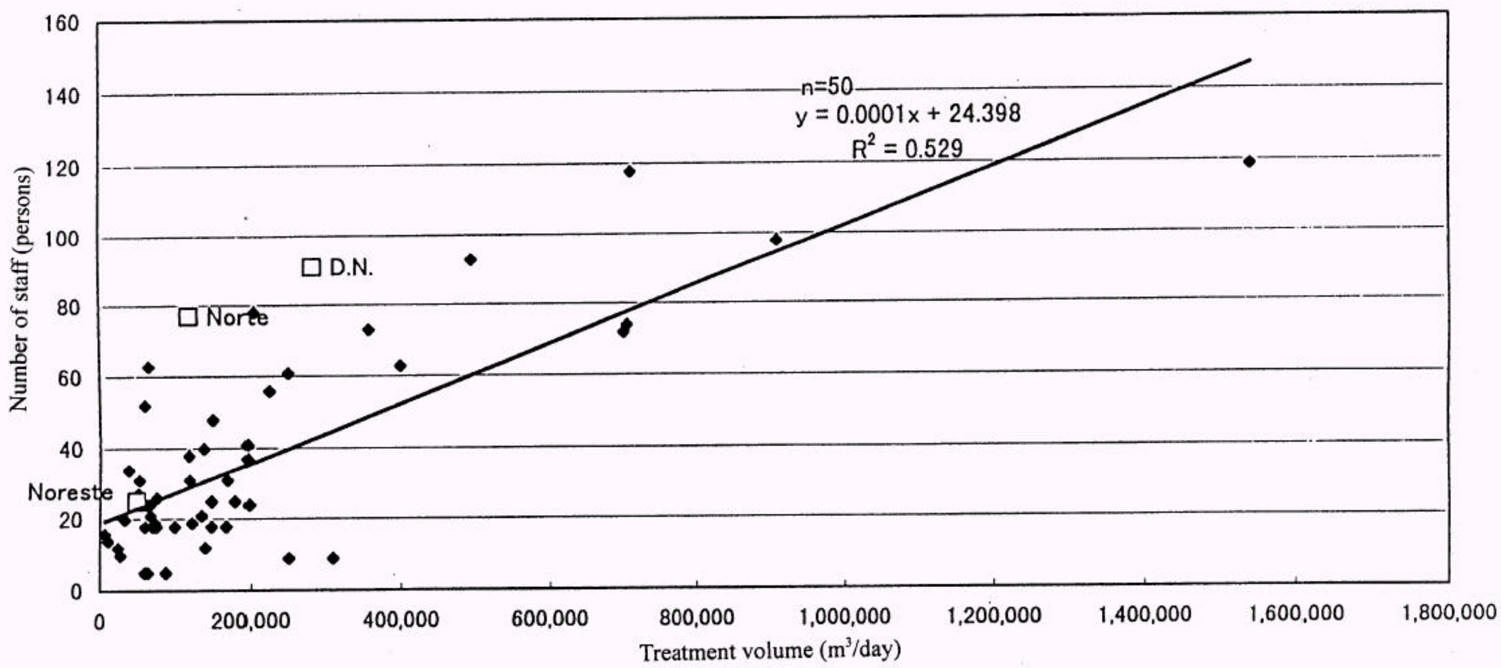


Note 1. The data consists of 3 places in Monterrey (as of 1999), 5 places in Kitakyushu (as of 1998), 5 places in Hiroshima City (as of 1998), 12 places in Osaka Prefecture (as of 1998), 2 places in Chiba City (as of 1998), 10 places in Tokyo (as of 1998), 9 places in Sapporo City (as of 1998), 4 places in Kawasaki City (as of 1998), and 15 places in Nagoya (as of 1998).

Note 2. The approximate curved line is for data in Japan.

(Source) Prepared from SADM materials, Kitakyushu City Construction Bureau (1999), Hiroshima City Sewerage Bureau (1999), Osaka Prefecture Civil Works Department Sewerage Section (1999), Chiba City Sewerage Bureau (1999), Tokyo Metropolis Sewerage Bureau (1998), Sapporo City Sewerage Bureau (1998) and Kawasaki City Construction Bureau (1998).

Figure 7 Number of Staff for Treatment Volume of Sewage Treatment Plants in Japan and Monterrey

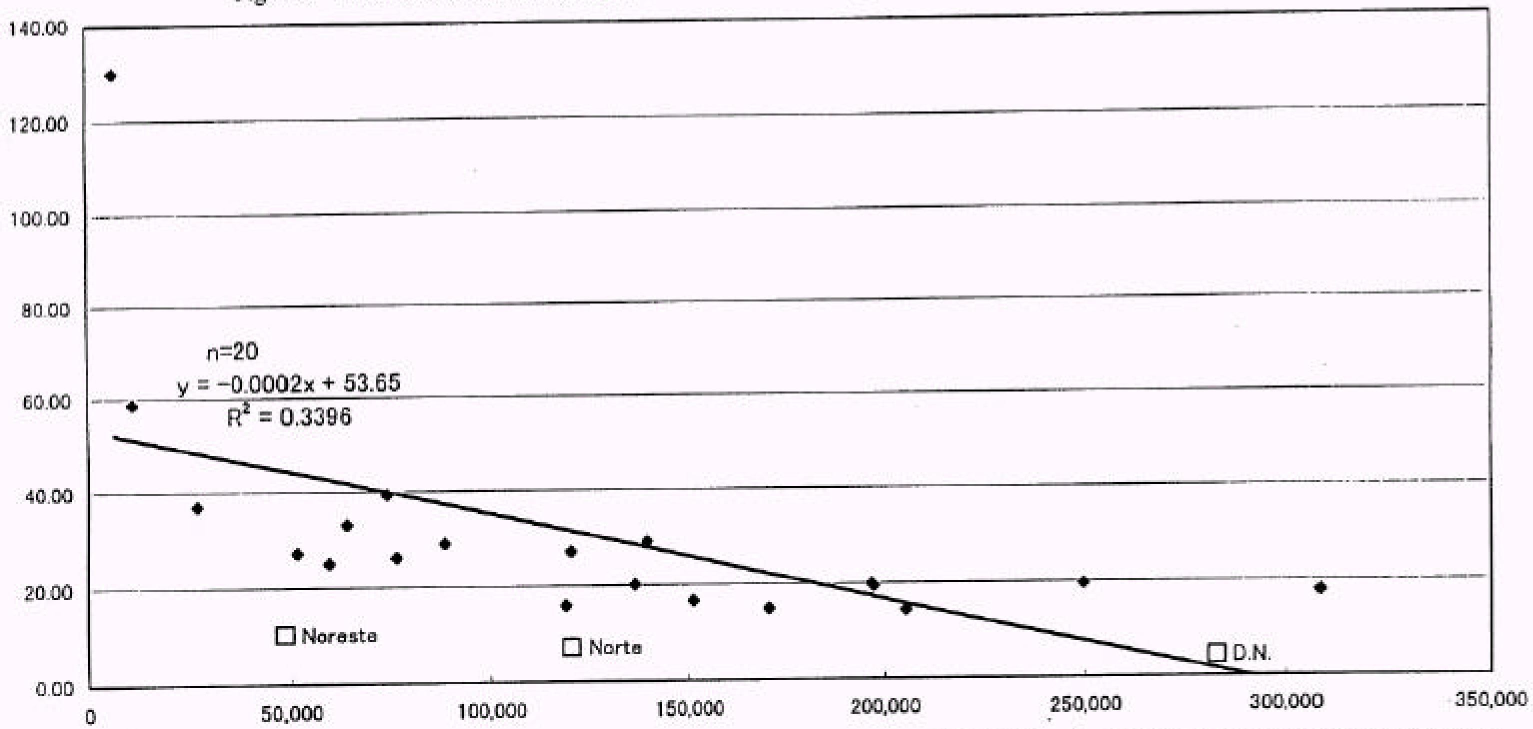


Note 1. The data consists of 3 places in Monterey (as of 1999), 5 places in Hiroshima City (as of 1998), 2 places in Chiba City (as of 1998), 10 places in Tokyo Metropolis (as 1998), 9 places in Sapporo City (as of 1998), 4 places in Kawasaki City (as of 1998), 5 places in Kitakyushu City (as of 1998) and 15 places in Nagoya (as of 1998).

Note 2. Numbers of staff of sewage treatment plants in Japan do not include "office work".

(Source) Prepared from SADM materials, Hiroshima City Sewerage Bureau (1998), Chiba City Sewerage Bureau (1998), Tokyo Metropolis Sewerage Bureau (1998), Sapporo City Sewerage Bureau (1998), Kitakyushu City Construction Bureau (1999) and Kawasaki City Construction Bureau (1998).

Figure 8 Treatment Cost (Yen/m³) for Treatment Volume of Sewage Treatment Plants in Japan and Monterrey

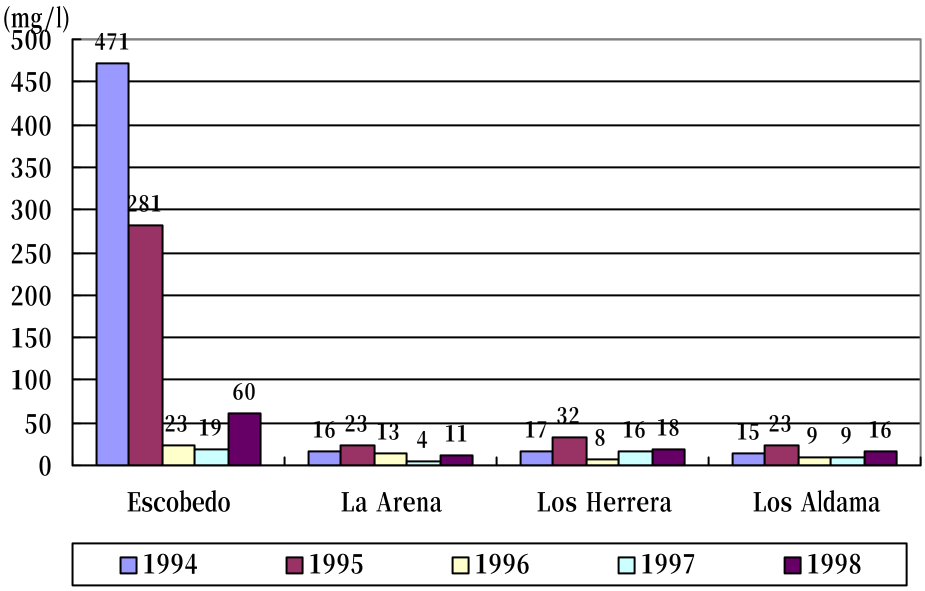


Note 1. The data consists of 3 places in Monterrey (as of 1998), 5 places in Kitakyushu (as of 1998), 2 places in Chiba City (as of 1998), 9 places in Sapporo City (as of 1998), and 4 places in Kawasaki City (as of 1998).

Note 2. The exchange rate was 1 peso = ¥13.75 (rate in May 1999).

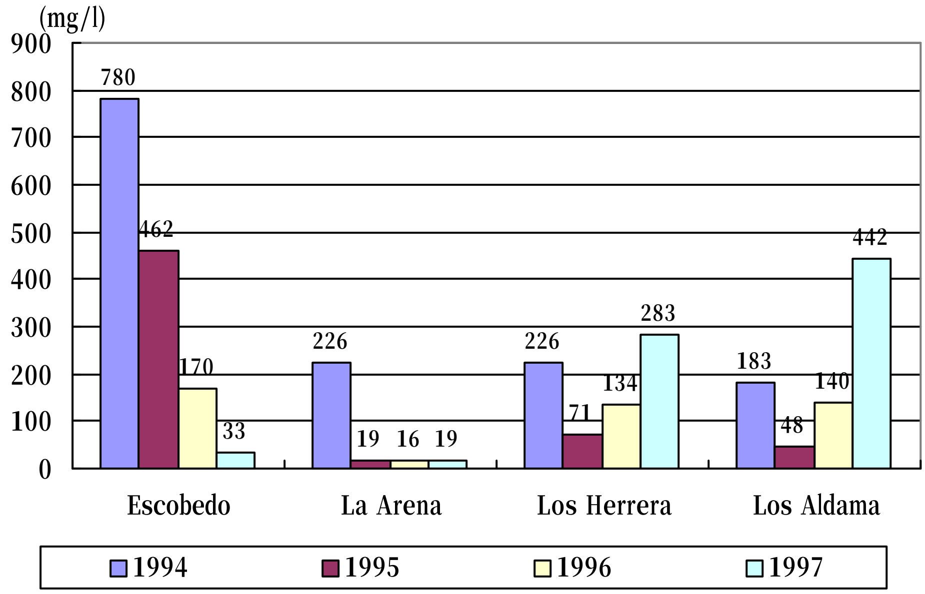
(Source) Prepared from SADM materials, Kitakyushu City Construction Bureau (1999), Chiba City Sewerage Bureau (1998), Sapporo City Sewerage Bureau (1998), and Kawasaki City Construction Bureau (1998).

Figure 9 BOD Change at the Pesqueria River (1994-1998)



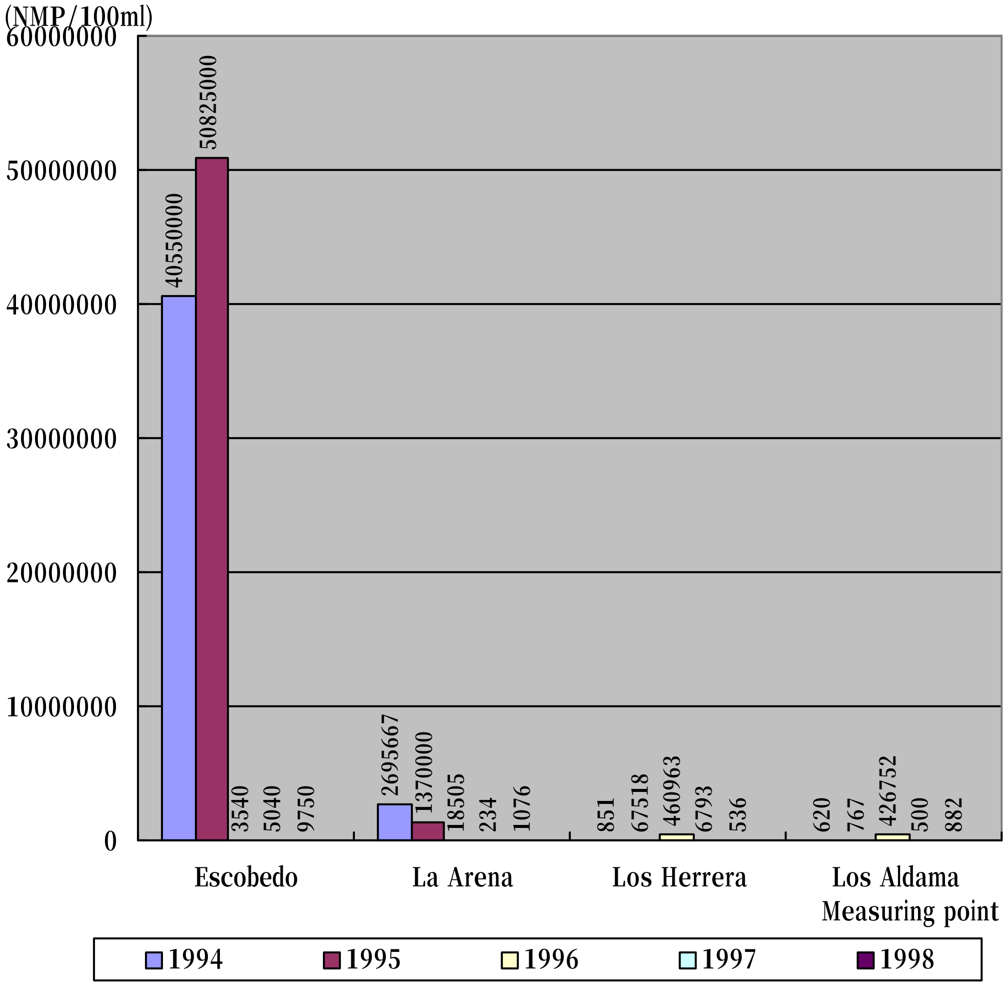
(Source) Prepared from CNA/Rio Bravo Office materials.

Figure 10 SS Change at the Pesqueria River (1994-1997)



(Source) Prepared from CNA/Rio Bravo Office materials.

Figure 11 Change of Numbers of Colon Bacilli at the Pesqueria River (1994-1998)



(Source) Prepared from CNA/Rio Bravo Office materials.

Table 1 Monterrey IV Master Plan (Expansion Parts of Water Supply and Sewerage Facilities)

		Objective	TORs
1st Stage	Clean water	In 1993 Attainment of supply capacity for 14.5m^3/s (1990 ratio + 5.0)	• Construction of Cuchillo Dam (10m^3/s) • Construction of the first aqua-duct (6m^3/s) • Construction of Sanroque pumping station (6m^3/s) • Extension of drain pipe for 5m^3/s increased portion
	Wastewater	Attainment of treatment capacity for 8.0m^3/s	• Extension of catchment pipe (131km) • Construction of wastewater treatment facility for 8.0m^3/s (5.0, 2.5, 0.5)
2nd Stage	Clean water	In 1996 Attainment of supply capacity for 19.5m^3/s (1990 ratio + 10.0)	• Construction of the second aqua-duct (6m^3/s) • Extension of Sanroque pumping station (6m^3/s)
	Wastewater	Attainment of treatment capacity for 11.4m^3/s	• Extension of existing treatment facilities to 11.5m^3/s (7.0, 3.5, 1.0)

(Source) Prepared from F/S.

Table 2 Detailed Plan for SADM Wastewater Portion

(Unit: m^3/s)

	D.N	Norte	Noreste
Fase 1	5.0	2.5	0.5
Fase 2 (2000)	7.5	3.75	2.5
Fase 3 (2005)	10.0	6.0	4.0

(Source) Prepared from the SADM homepage.

Table 3 Planned Water Quality

Index	Before inflow	After treatment
BOD	200	30
COD	654	60
TSS	347	30
S Set (Ml/l)	13.4	0
$N\text{-}NH_3$	14	2
N Org	23.5	8
PO_4	14.2	7
Grease and Oil	114	10
Total Coliforms (NMP/100ml)	3.6×10^{7}	＜1000

Note The figures without units are all mg/l.

(Source) Prepared from JBIC materials.

Table 4 Overflow Situation of Noreste

Year	1995	1996	1997	1998	1999
Overflow volume (l.p.s)	0	18.7	111.5	183.0	266.0

(Source) Prepared from SADM materials.

Table 5 Change of Flux in the Pesqueria River Area

(m^3/year)

	1993	1994	1995	1996	1997	1998	Average for 1993-1998	Average for 50 years
El Canada (Escobedo)	7.112	16.397	12.613	32.824	35.149	28.514	22.102	12.773
La Arena	120.246	60.987	66.672	148.918	81.646	51.623	88.349	102.888
Los Herrera	133.137	120.637	162.150	115.182	165.032	106.475	133.769	162.182
Los Aldama	332.134	120.451	191.682	423.484	283.389	110.271	243.569	975.490

(Source) Prepared from CNA/Rio Bravo Office materials.

Table 6 Comparison of Water Quality for Treatment at Each Treatment Plant (Actual in 1997)

		D.N	Norte	Noreste
Inflow water	BOD (mg/l)	355	342	150
	SS (mg/l)	468	460	185
	$N\text{-}NH_3$ (mg/l)	24	68	15
	Colon bacilli (/100ml)	-	-	-
Discharge water	BOD (mg/l)	6.1	10	15
	SS (mg/l)	20.5	26	11
	$N\text{-}NH_3$ (mg/l)	1.4	35	0.3
	Colon bacilli (/100ml)	336.8	314.7	384.1

(Source) Prepared from SADM(1998) and SADM materials.

Table 7 Outline of Monterrey Sewerage Treatment Plant

		Dulces Nombres	Norte	Noreste	Total
Plottage (ha)		136	48	18.36	202.36
Used area (ha)		25	22	4	51
Planned treatment population (1,000 people)		1,800	860	240	2,900
Treatment capacity	Average m^3/s	5.00	2.50	0.50	8.00
	Lowest m^3/s	2.60	1.12	0.16	3.88
	Maximum per hour m^3/s	9.50	5.33	0.93	15.76
	Maximum per day m^3/s	6.80	4.39	0.75	11.94
Treatment method		Activated sludge process (net oxygen process)	Activated sludge process (standard process)	Activated sludge process (long-term aeration process)	—
Construction cost (¥1 million)		6,699.0	4,797.7	1,692.0	13,188.7
Completion date of facilities		February 1996	July 1995	May 1995	—
Starting date of use		February 1996	December 1995	July 1995	—
Actual in 1998	Treatment water volume (m^3/s)	3.23	1.37	0.56	5.16
	Number of staff (persons)	91	77	25	193
	Maintenance cost (annual: peso)	33,613,339	22,742,742	17,526,806	69,634,418
	Dried sludge occurrence volume (annual: t)	26,559	16,150	4,477	47,186
	Energy consumption volume (kw/m^3)	0.49	0.51	0.62	1.62

(Source) Prepared from SADM materials.

Table 8 Comparison Among Treatment Plants at Monterrey Sewerage Treatment Plant (Actual in 1998)

	Dulces Nomblres	**Norte**	**Noreste**
Treatment water volume (m^3/s)	3.23	1.37	0.56
Number of staff (person/m^3s)	28.15	56.08	44.96
Treatment cost (peso/m^3)	0.33	0.53	0.76
Sludge occurrence volume (kg/m^3)	0.26 (0.261)	0.37	0.26 (0.255)
Energy consumption volume (kw/m^3)	0.49	0.51	0.62

(Source) Prepared from SADM (1998).

Table 9 Transition of Maintenance Cost

(Unit: US$1,000)

	Plan (per 5m^3/s)	Actual (per 5m^3/s)
1995	14,951	1,621
1996	14,951	6,159
1997	14,951	6,618
1998	14,951	8,538

(Note) Actual values are based on exchange rates for each between 1995 and 1997, and US$1=7.9 peso (1997 exchange value) for 1998.

(Source) Prepared from SADM(1998) and SADM materials.

Table 10 History of SADM

1906	Start of water supply and sewerage services by "Monterrey Water-Works and Sewage, Limited" in Toronto, Canada
1945	The above-mentioned company was taken over by Nuevo León State and Monterrey Bank of Commerce was commissioned to do management
1956	"Servicios de Aguay Drenaje de Monterrey" was established for the purpose of providing water supply and sewerage services for residents in Monterrey metropolitan area based on Nuevo León State Law.
1995	Overall Nuevo León became under the jurisdiction of SADM by dissolution of "SISTELEON".

(Source) Prepared from SADM homepage (http://www.aquaydrenajemty.gob.mx/organigrama.htm)

Table 11 Impacts of the Monterrey Wastewater Project

	Anticipated impact	Unanticipated impacts
Positive	Improvement of river water quality and contribution to downstream water use.	The ability of the SADM increased to such an extent that it was able to take on centralized management of the sewage treatment plants.
Negative		The volume of water drawn for irrigation in the Pesqueria River increased, aggravating water disputes.

Source: Prepared by the author.