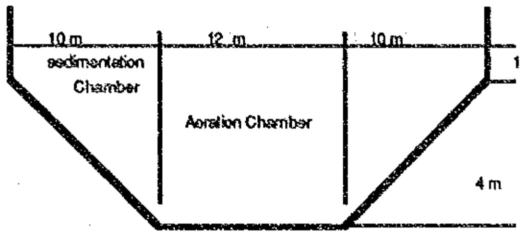
50,313 / (12 x 5 + 10 x (1+5)/2 x 2) = 419 m

By fixing the tank length at 110 m, the number of tanks becomes 4.



D. Sludge Digestion

- Inlet sludge (concentration 4 %)

$250 \times 10^{-6} \times 1.4 \times 230{,}000 / 0.04 = 2013\ m^3/day$

- Solids in the digested sludge (assuming loss by digestion is 20 % and by supernatant is 14 %)

2013 x 0.04 x (1 - 0.2 - 0.14) = 53.1 ton/day

- Amount of the digested sludge (concentration 6 %)

$53.1 / 0.06 = 885\ m^3/day$

- Required volume of digestion (detention time 30 days)

$(2013 + 885) / 2 \times 30 = 43{,}470\ m^3$

- Dimension and number

Diameter 30 m, depth 9 m, number 8 (50,864 m^3)

E. Sludge Drying Bed

-Sludge amount 885 m^3/day

- Drying period 10 days

- Depth 0.2 m

- Required area

$$885 \times 10 / 0.2 = 44,250 \ m^2$$

The general layout of the wastewater treatment plant is shown in Figs. 5.2.6 .

5.2.3 Alternatives for the Basic Plan (Lipari Option)

(1) Availability of Plant Sites

Four sites were considered to be available for a wastewater treatment plant site. Two are located upstream of the Lipari Bridge and the other two downstream as shown in Fig. 5.2.7. The area of all sites are presented in Table 5.2.5.

For the selected sites, the site plan proposes to grade the land by filling the river bed and cultivated areas. Boundaries along the river were determined so as to leave a sufficient cross section to accommodate the 100 year flood discharge.

TABLE 5.2.5 POSSIBLE LANDS FOR A WASTEWATER TREATMENT SITE NEAR THE LIPARI BRIDGE

Site No.	Name (Location)	Total Area (ha)	River Bed (ha)	Cultivated Area (ha)
1	Jupapina	23.0	14.8	8.2
2	Upstream of the Lipari Bridge	16.0	14.2	1.8
3	Downstream of the Lipari Bridge	14.6	7.1	7.6
4	Confluence with the Achocalla River	20.8	9.6	11.2

The estimated available areas for these sites varies from 15 ha to 23 ha. Since site #2 and site #4 are influenced by the Huacallani River and the Achocalla River, respectively, the available sizes of these sites will each be reduced by about ten percent. Site #1 has the largest land area and is located farthest upstream among the four, which would result in a reduced length of required main sewer interceptor. Thus Site #1 is preferred if only one site is selected from the four. In addition, there are no buildings at or near Site #1, while several houses exist at the other sites.

For the Irpavi option, a high rate activated sludge method was selected as the treatment alternative due to area limitations. In the Lipari option, however, it would be possible by using more than one site to select treatment methods that require less construction/operations costs but more land.

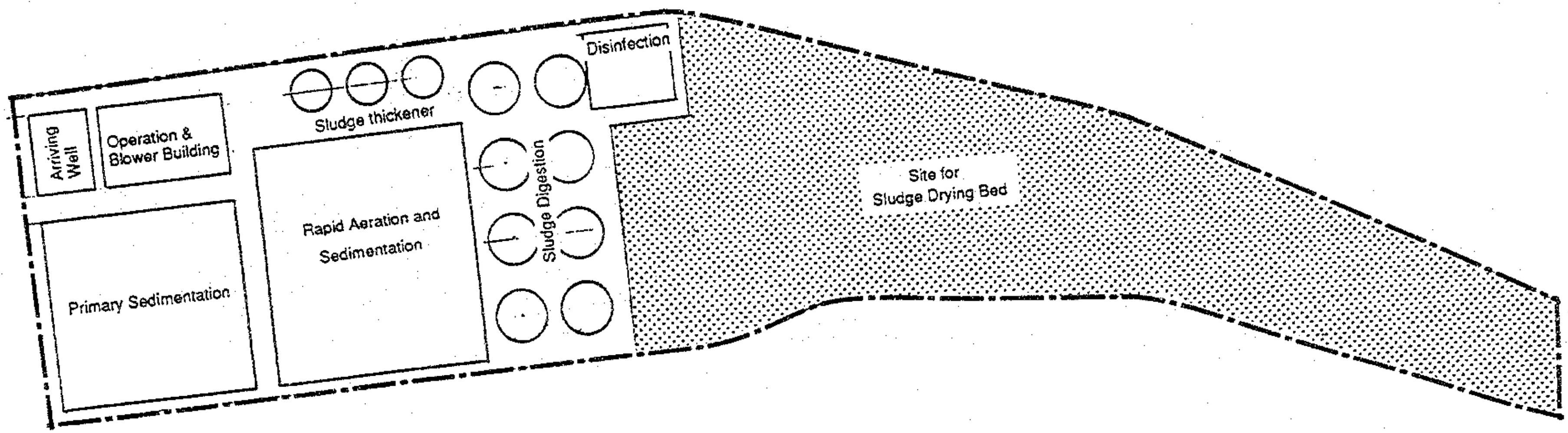


Fig. 5.2.6 General Layout of Wastewater Treatment Plant (Irpavi Option)

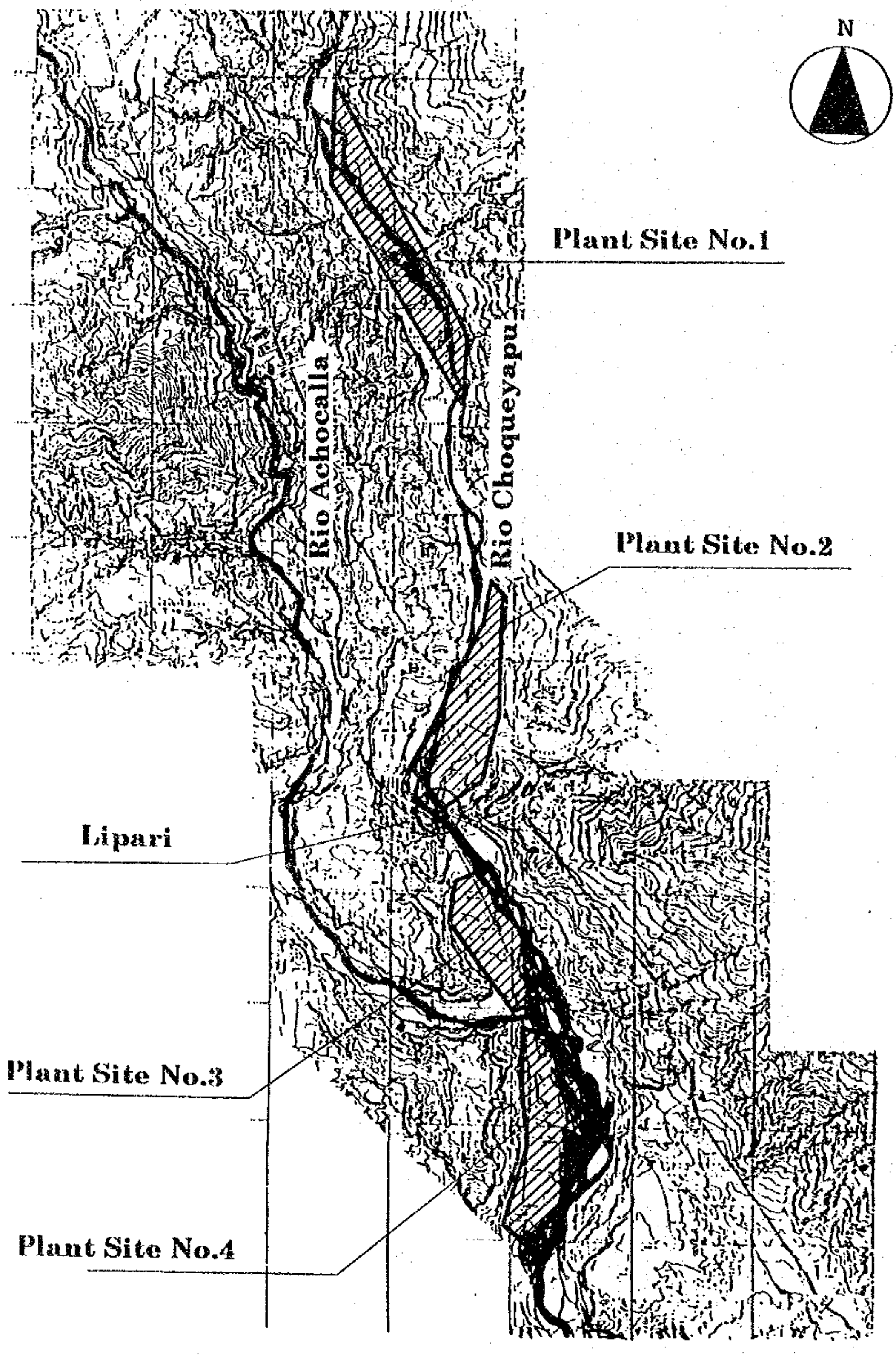


Fig. 5.2.7 Locations of Plant Sites for the Lipari Option

(2) Sewage Collection/Transmission

In the Lipari option, a main sewer interceptor would be installed from the intake facilities upstream of the Choqueyapu-Orkojahuira confluence to the wastewater treatment plant site above the Lipari bridge. This main interceptor would collect wastewater from the central area, the Irpavi basin, and other areas, and transmit them to the plant site.

The proposed route of the main sewer interceptor follows the existing roads from the water intake weir to the Aranjuez bridge, including a river crossing at Calacoto. However, in the section between the Aranjuez bridge and the Lipari bridge, there is no road along the river due to steep topographical conditions. The road below Aranjuez leaves the river and winds up the steep hill to Moon Valley. It would be impractical to install the sewer main along the road between Aranjuez and Lipari. Therefore, the selected route follows generally along the river below the Aranjuez bridge.

In most of this reach, the river runs at the bottom of a steep valley with a flood plain width of several tens of meters. The interceptor can be buried under the flood plain in such sections. However, there is a short reach just below Aranjuez where the river flows through a narrow steep valley and there is almost no space for the interceptor installation. It is proposed to construct a tunnel bypassing this reach, because construction would be very difficult and expensive in the narrow steep valley. Also, the length of the tunnel would be considerably less than that along the river course.

The proposed route of the main sewer interceptor, which was selected after discussion with the Bolivian counterparts, is shown in Fig. 5.2.8.

(3) Treatment Method

Wastewater treatment methods for a centralized plant of the Irpavi option were discussed in the previous section. In the Irpavi option, a high-rate activated sludge treatment was selected because of area limitations, although it was not preferable from the viewpoints of cost and suitability of technology.

In the case of the Lipari option, it was possible to consider other methods, which require more land area but less construction costs, such as aerated lagoons or ponds.

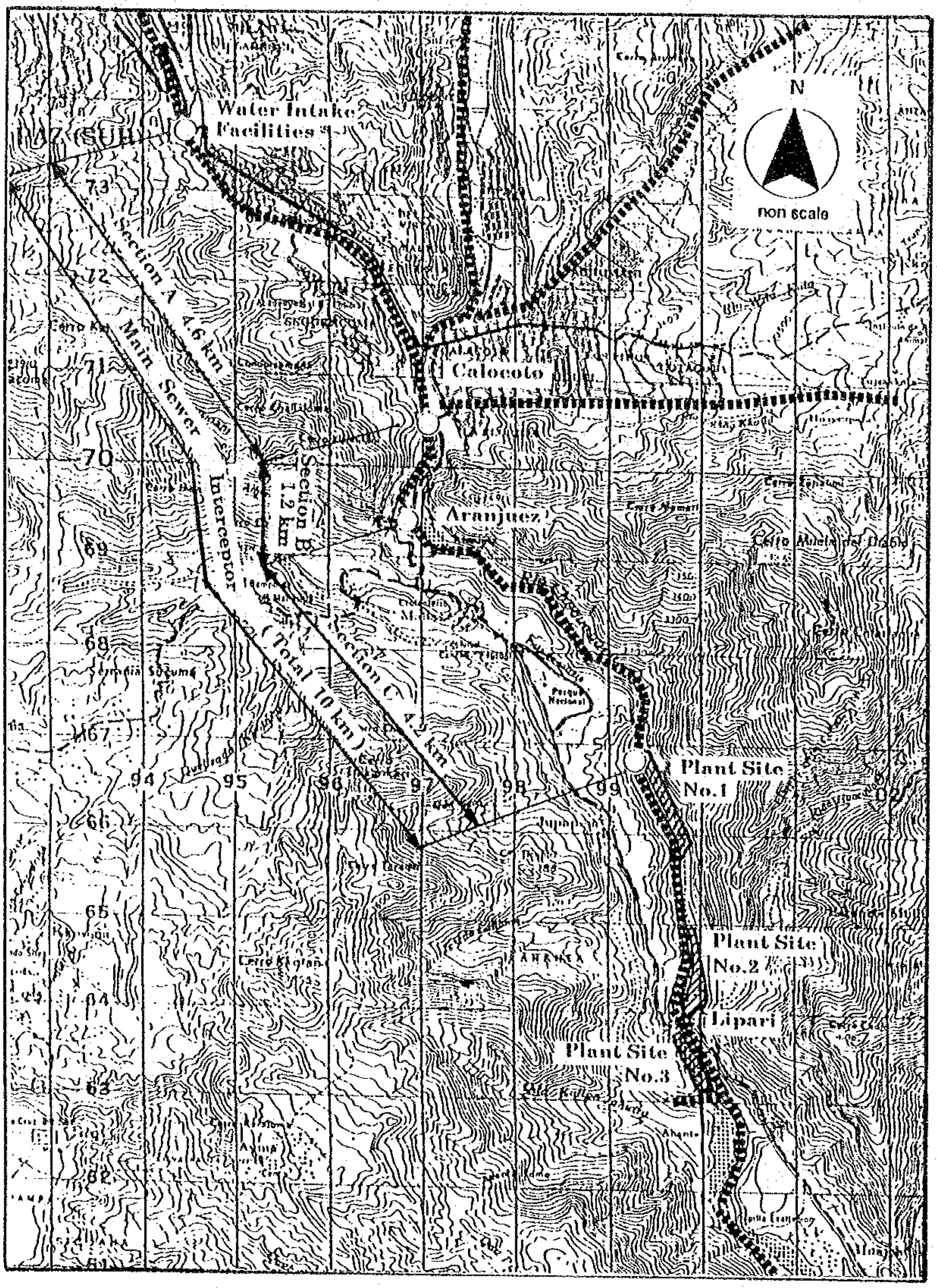


Figure 5.2.8 Route of Main Sewer Interceptor (Lipari Option)

Typical design parameters for several types of stabilization ponds are shown in Table 5.2.6.

TABLE 5.2.6 TYPICAL DESIGN PARAMETERS FOR SEVERAL TYPES OF STABILIZATION PONDS

Parameters	Type of Ponds		
	Aerobic lagoons (high rate)	Facultative lagoons	Aerated lagoons
Flow Regime	Intermittently mixed	Mixed surface layer	Completely Mixed
Pond size (ha)	0.2 - 0.8	0.8 - 4	0.8 - 4
Operation	Series	Series or parallel	Series or parallel
Detention time (day)	4 - 6	5 - 30	3- 10
Depth (m)	0.3 - 0.5	1.2 - 2.4	2 - 6
Temperature (°C)	5 - 30	0 - 50	0 - 30
BOD conversion (%)	80 - 95	80 - 95	80 - 95

Extract from Metcalf & Eddy, Wastewater Engineering: Treatment, Disposal and Reuse: Third Edition, MacGraw Hill, Inc. New York, N.Y., (1991)

Table 5.2.7 shows the areas required to treat the wastewater by stabilization ponds, calculated by the design parameters (using minimum detention times and maximum depths) shown in Table 5.2.6. The required areas for aerobic lagoons and facultative lagoons exceed the total area of four sites (refer to Table 5.2.5), thus, these methods cannot be applied as treatment alternatives for the Lipari option. Aerated lagoons are considered to be applicable from the stand point of the required area even though they will require higher operating costs and further areas for sedimentation and sludge storage. Therefore, aerated lagoons are one of the alternatives selected for the Lipari option.

TABLE 5.2.7 REQUIRED SIZES OF POND TO TREAT WASTEWATER BY SEVERAL TYPES OF STABILIZATION PONDS (LIPARI OPTION)

(DESIGN WASTEWATER FLOW = 230,000 m3/day)

Type of Ponds	Detention Time (day)	Volume of Ponds (m3)	Depth (m)	Size of Ponds (ha)*
Aerobic Lagoons	4	920,000	0.5	184
Facultative Lagoons	5	1,150,000	2.4	48
Aerated Lagoons	3	690,000	6.0	12

* Assumes vertical side slope. Gross areas (considering side slopes, unusable lands, access roads, buildings, parking, etc.) would be about twice those shown.

The trickling filter process, which was eliminated from consideration for the Irpavi option due to its area requirements, could also be applied as a treatment method for the Lipari option. This method has advantages with regard to area requirements and operating costs as compared to the aerated lagoons.

5.2.4 Selected Alternatives

In the Basic Plan, it is proposed:

i) to collect the wastewaters from the Central area (excluding the Orkojahuira catchment) by taking dry season flow of the Choqueyapu River at Kantutani; upstream of the confluence with the Orkojahuira River.

ii) to install a main sewer interceptor between the water intake point at the Choqueyapu River and the proposed wastewater treatment site, to transmit the wastewaters from the Central area and the other areas to the plant site

iii) to install sewer interceptors in other areas not including the Central area, to collect wastewaters from the existing sewer pipes and to connect to the main sewer interceptor

iv) to construct one centralized wastewater treatment plant to treat the wastewaters.

There are two general plant site alternatives as follows:

i) A site located on the left bank of the Irpavi River in Calacoto area (Irpavi option)

ii) One or more sites located along the Choqueyapu River upstream and downstream of the Lipari bridge (Lipari option)

For the Irpavi option, it was determined that the activated sludge method (high-rate activated sludge) is the only applicable method for wastewater treatment because of area limitations. For the Lipari option, it is considered that aerated lagoons and trickling filters, which have been eliminated from the Irpavi option because of their land requirements, are applicable, as well as activated sludge. Therefore, the basic plan will be selected from the four alternatives shown in Table 5.2.8.

TABLE 5.2.8 DESCRIPTIONS OF ALTERNATIVES FOR BASIC PLAN

Options	Alternatives	Plant site	Treatment method	Main Sewer Interceptor
Irpavi	1	Left bank of the Irpavi river in the Calacoto area	High Rate Activated Sludge	from the upstream of the confluence with the Orkojahuira river to Irpavi, mainly along roads.
Lipari	2A	Near Lipari, #1	Conventional Activated Sludge	from the upstream of the confluence with the Orkojahuira river to Lipari, along roads and river beds.
Lipari	2B	Near Lipari, #1	Trickling filters	same as above
Lipari	2C	Near Lipari, #1, #2 and #3	Aerated Lagoons	same as above

5.3 EVALUATION OF THE ALTERNATIVES

5.3.1 Costs Comparison

(1) Estimates of Construction/Operation Costs

Cost estimates were prepared for four alternatives.

Tables 5.3.1 and 5.3.2 show construction cost estimates for the main sewer interceptor (including water intake facilities) of the Irpavi and Lipari options.

TABLE 5.3.1 PRELIMINARY ESTIMATES OF CONSTRUCTION COSTS FOR MAIN SEWER INTERCEPTOR (IRPAVI OPTION, 1992 PRICES)

Sections	Unit	Quantity	Unit Price	Total
Main Roads	lm	3640	$861	$3,134,040
Tunnel	lm	900	$1500	$1,350,000
Total				$4,484,040

TABLE 5.3.2 PRELIMINARY ESTIMATES OF CONSTRUCTION COSTS FOR MAIN SEWER INTERCEPTOR (LIPARI OPTION, 1992 PRICES)

Sections	Unit	Quantity	Unit Price	Total
Main Roads	lm	3630	$861	$3,125,430
Secondary Roads	lm	1260	$745.5	$939,330
Populated Area	lm	485	$811.5	$393,578
Tunnel	lm	260	$1500	$390,000
River Bed *	lm	4215	$1000	$4,215,000
Sub Total				$9,063,338

* Includes access roads and protection over pipe.

Construction costs for three types of wastewater treatment plant are shown in Table 5.3.3. Operation costs for three types of wastewater treatment are shown in Table 5.3.4. Costs estimates for wastewater treatment methods were prepared on the basis of data from several references published in the U.S.A., especially from References E5 and E6. In the absence of cost data from similar wastewater treatment plants in the high elevations of Bolivia, this cost data is believed to be the best available information for these studies. Although unit prices for civil works are less expensive in Bolivia than in the U.S.A., this is offset by imported equipment costs and special design consideration related to the altitude in the study area. Cost estimates for the priority project will be developed in more detail in Part III, Feasibility Study.

TABLE 5.3.3 PRELIMINARY ESTIMATES OF CONSTRUCTION COSTS FOR WASTEWATER TREATMENT PLANT BY TREATMENT METHODS ($U.S. MILLION, 1992 PRICES) Design Wastewater = 230,000 m3/day

Aerated Lagoons		Trickling Filters		Activated Sludge	
Site Preparation (40ha)	8.50	Site Preparation (20ha)	4.50	Site Preparation (20ha)	4.50
Preliminary Treatment	1.20	Preliminary Treatment	1.20	Preliminary Treatment	1.20
Aerated Lagoons	4.50	Preliminary Clarifier	4.80	Preliminary Clarifier	4.80
Sedimentation Basins	2.00	Trickling Filters ***	16.50	Activated Sludge ***	18.0
Sludge Lagoons	1.20	Sludge Digesters	6.00	Sludge Digesters	6.00
Interface Piping	0.45	Sludge Drying Beds	4.50	Sludge Drying Beds	6.70
Electr. & Instrum	0.57	Interface Piping	3.75	Interface Piping	4.12
Operation Building *	0.30	Electr. & Instrum	3.38	Electr. & Instrum	3.60
Miscellaneous Buildings **	0.20	Operation Building *	0.40	Operation Building *	0.40
Access Roads	0.20	Miscellaneous Buildings **	0.30	Miscellaneous Buildings **	0.30
		Access Roads	0.20	Access Roads	0.20
Total	19.12	Total	45.53	Total	49.82

* Office, lab, meeting, etc
** Garage, storage, maintenance
*** Includes Final Clarifiers/Recycle Pumps.

TABLE 5.3.4 PRELIMINARY ESTIMATES OF ANNUAL OPERATION COSTS FOR WASTEWATER TREATMENT PLANT BY TREATMENT METHODS ($U.S. MILLION, 1992 PRICES)

Aerated Lagoons		Trickling Filters		Activated Sludge	
Aerated Lagoons	2.60	Trickling Filters	1.10	Activated Sludge	3.00
Sludge Lagoons	0.08	Preliminary Clarifier	0.25	Preliminary Clarifier	0.25
		Digesters	0.10	Digesters	0.10
		Sludge Drying Beds	0.70	Sludge Drying Beds	0.90
Haul Sludge	0.08	Haul Sludge	0.03	Haul Sludge	0.03
Total	2.76	Total	2.18	Total	4.28

Note: Does not include preliminary treatment, which is common to all alternatives.

(2) Project Costs

Based on the construction/operation costs shown above, project costs for four alternatives were estimated as shown in Table 5.3.5. The total project cost estimates presented herein include Engineering (final design and construction supervision), estimated at 10% of construction costs, and Contingencies, estimated at 15% of construction costs.

TABLE 5.3.5 COMPARISON OF ALTERNATIVES ($U.S. MILLION, 1992 PRICES)

	Alternatives			
Costs	1	2 A	2 B	2 C
Capital Costs				
Main sewer Interceptor	4.48	9.06	9.06	9.06
WWTP	49.82	49.82	45.53	19.12
Intake Facilities	1.15	1.15	1.15	1.15
Sewer interceptors	3.22	3.22	3.22	3.22
Sub-Total	58.67	63.25	58.96	32.55
Land and R.O.W.'s	17.25	2.94	2.94	5.34
Engineering	5.87	6.33	5.90	3.26
Contingency	8.80	9.49	8.84	4.88
Total	90.59	82.00	76.64	46.03
Annual Operation Costs	5.00	5.00	2.50	3.50

Note: For descriptions of each alternative, refer to Table 5.2.8.

5.3.2 Technological Adaptability

Required technological levels in the operation and maintenance of treatment facilities are qualitatively compared below for the treatment methods of the four basic plan alternatives.

Method	Basic plan Alternative No.	Simplicity of operation	Ease of maintenance	Local availability of equipment /supplies	Level of personnel skill required
Activated sludge	1 2-A	xx	xxx	xx	x
Trickling filter	2-B	xx	xx	xxx	xx
Aerated lagoon	2-C	xxx	xxx	xxx	xx

Note: xxx : simpler, easier, higher availability, lower level of skill
xx : medium
x : not simple, not easy, lower availability, higher level of skill

The aerated lagoon method is considered to be most favorable among the three methods with respect to appropriateness of technology, followed by the trickling filter method and the activated sludge method. It should be noted that the sludge treatment for the activated sludge and the tricking filter methods would require heated/mixed digesters. They may present operational problems and require imported equipment and spare parts.

5.3.3 Water Quality Improvement for Various Cases

(1) Cases Studied

Expected water quality improvement effects of the Irpavi and Lipari options in terms of BOD were predicted using the simulation model described in Chapter 4. Water quality improvement effects of the three Lipari alternatives were assumed to be essentially the same. The computations were carried out for the following cases for 2010:

i) Implementation of the Irpavi option

ii) Implementation of the Lipari option

iii) Industrial wastewater control (Applying the effluent standards, maximum 300 mg/l of BOD, to industries with wastewater discharge over 100m^3/day)

iv) Industrial wastewater control (Applying the effluent standards, maximum 300 mg/l of BOD, to industries with wastewater dischargeover 25m^3/day)

v) Dilution by water from a dam (0.2m^3/sec)

Cases iii) and iv) were included to compare the effects of applying the industrial wastewater discharge regulation to relatively large industries only and applying the regulation to industries including smaller ones. Case v) was included, for reference, to see the effect of diluting the river water by dam discharge.

(2) Predicted Effects

The predicted BOD concentrations along the Choqueyapu river for above cases are summarized in Table 5.3.6.

TABLE 5.3.6 COMPARISON OF THE WATER QUALITY IMPROVEMENT EFFECTS BY VARIOUS MEASURES (2010)

(unit: mg/l BOD)

Evaluation Point	Present (1992)	Estimated water Quality in 2010					
		Uncontrolled	Implementation of the Irpavi Option	Implementation of the Lipari Option	Applying Wastewater Discharge Control		Dilution by Dam Water
					Industries over 100 m^3/d	Industries over 25 m^3/d	
R1	1.2	1.2	1.2	1.2	1.2	1.2	1.2
R2	2.2	2.2	2.2	2.2	2.2	2.2	2.2
R3	67.8	70.4	70.4	70.4	54.6	48.8	58.1
R4	151.7	147.6	147.6	147.6	116.1	112.2	135.6
R5	143.0	138.7	138.7	138.7	119.0	116.2	130.8
R9	107.1	106.7	8.5	8.5	95.9	93.9	115.6
R14	71.1	87.7	26.1	49.2	81.4	80.1	85.1
R15	54.3	72.1	23.1	46.4	67.3	66.3	70.3

The effects of the Irpavi option and the Lipari option are compared, in Fig.5.3.1, with the present water quality and the future uncontrolled water quality in the year 2010. The effect of the Irpavi option for the lower reach is more profound than that of the Lipari option. The BOD values at Lipari Bridge (R15) in 2010 are 23 mg/l in the Irpavi option, 49 mg/l in the Lipari option, and 68 mg/l in the uncontrolled case. The results indicate that the water quality target would be achieved at the Lipari bridge by either option of the basic plan. At Calacoto (R9), another evaluation point of the water quality target, its BOD is estimated at 8.5 mg/l in both options. This is because in both cases the entire dry-season flows of the Choqueyapu and Kantutani Rivers and all wastewater in the Orkojahuira basin will be diverted through the pipeline to the wastewater treatment plant. Therefore, although there would be only a little water in the dry season, the present adverse conditions in this area such as obnoxious odors would be greatly improved.

Fig. 5.3.2 shows the effects of the implementation of the industrial wastewater discharge regulation. As can be seen from the figure, the industrial wastewater discharge control will improve the river water quality, but it is not sufficient to achieve the water quality target. A difference in the effect between two cases, 100 m^3/day and 25 m^3/day, is negligible, indicating that the improvement can be achieved effectively by controlling only large scale industries.

Fig. 5.3.3 shows the effect of dilution water from a dam being discussed to construct in the upstream of the Choqueyapu river. Having no reliable information, the yield of the dam was assumed to be 0.2 m^3/sec, which is less than 10 % and 5 % of the flow rate at R9 and R15, respectively. Since the dilution rate is small, the expected effect is negligible.

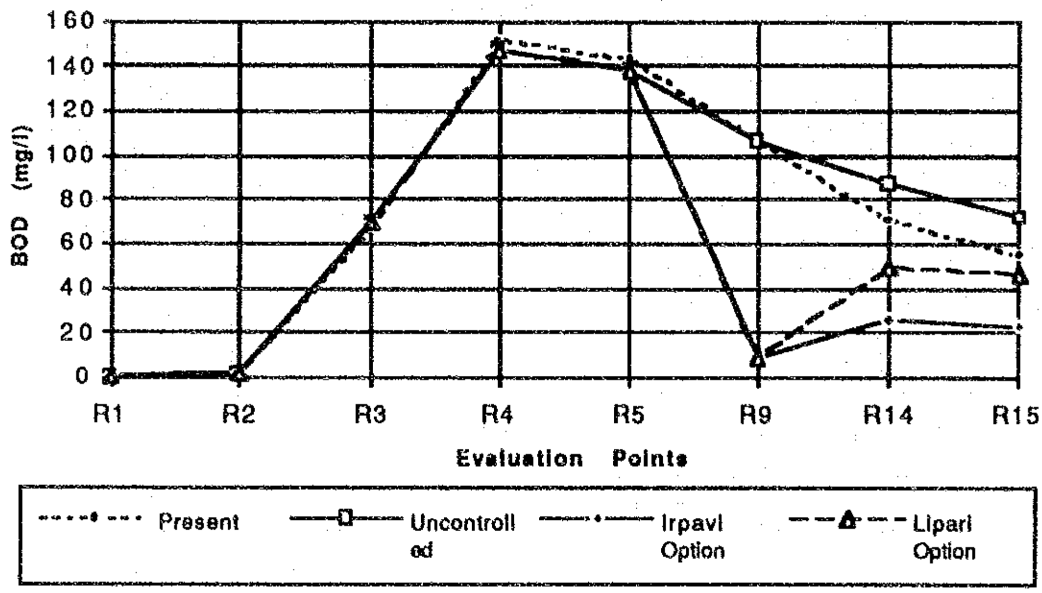


Fig. 5.3.1 EFFECTS OF STRUCTURAL MEASURES FOR BASIC PLAN (Year 2010)

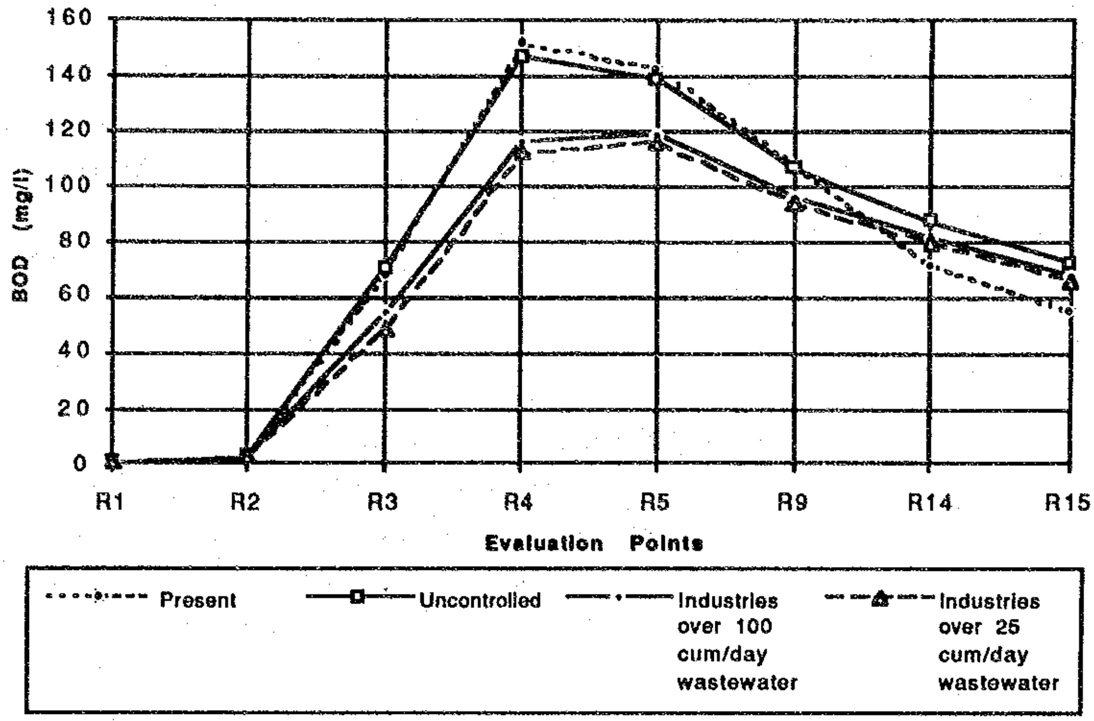


Fig. 5.3.2 EFFECTS OF INDUSTRIAL WASTEWATER CONTROL

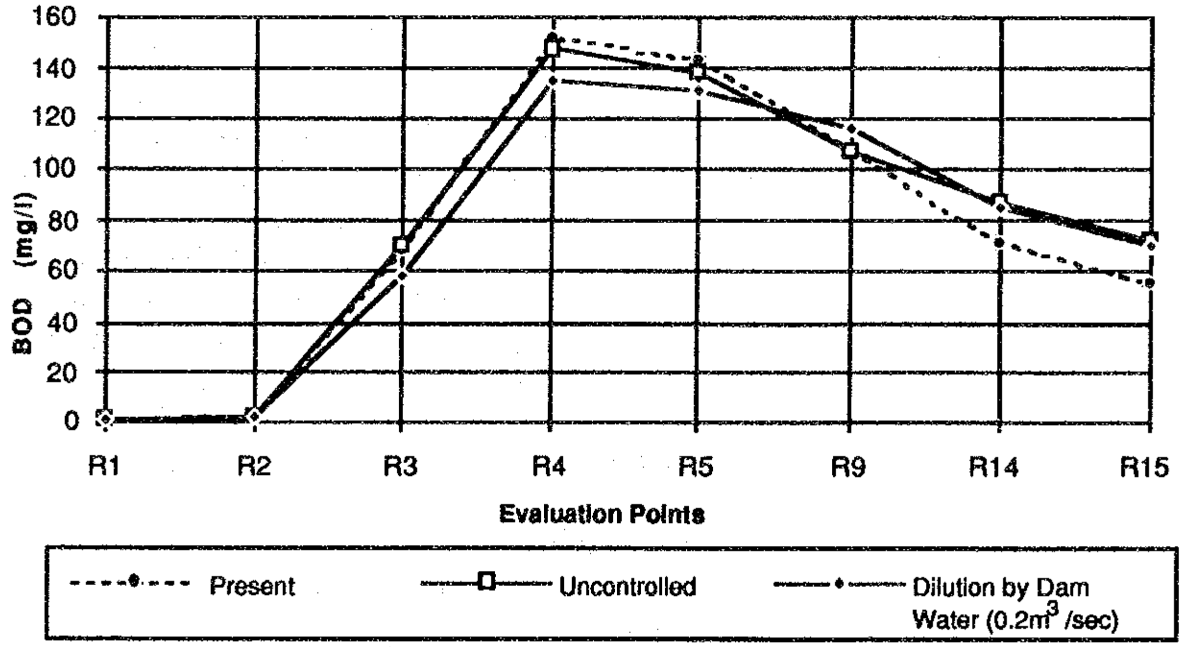


Fig. 5.3.3 EFFECTS OF DILUTION BY DAM WATER

5.3.4 Social and Environmental Impacts

Implementation of any of the basic plan alternatives will bring about various social and environmental impacts. Potential impacts are qualitatively analyzed for each of the four alternatives, in the form of a checklist, as shown in Tables 5.3.7 . Explanations on the checklist are given below.

(1) Social Environment

1) Transportation/Public Facility

During the construction period of the main sewer interceptor and other sewer interceptors that are generally installed under the existing roads, there will be certain inconveniences in road traffics, although they will be temporary. This impact will be greater for the three Lipari alternatives (2A, 2B and 2C) than for the Irpavi alternative (1), since the length of the interceptor in the roads is longer in the Lipari alternatives.

The Irpavi site is presently designated for the development of an educational complex. There is also a construction plan for a peripheral road passing through the site along the Irpavi river. Therefore, locating the treatment plant at this site would have a significant impact.

2) Agriculture/Water Use

All four alternatives would have a significant positive impact on the irrigation use of the Choqueyapu river water in the downstream farmlands.

However, the three Lipari alternatives require some of the farmland(s) around Lipari to be taken for the treatment plant. This impact on agriculture is greater in the alternative 2C (aerated lagoon) since the required area is greater than that in the alternatives 2A (activated sludge) and 2B (trickling filter).

3) Public Health/Sanitation

All four alternatives will contribute to significantly improve the sanitation conditions around the lower section of the Choqueyapu River and the urban sections of the other main tributaries.

TABLE 5.3.7 CHECKLIST FOR SOCIAL/ENVIRONMENTAL IMPACT

Alternative 1 : Irpavi - High-rate Activated Sludge
Alternative 2A : Lipari - Conventional Activated Sludge
Alternative 2B : Lipari - Trickling Filter
Alternative 2C : Lipari - Aerated Lagoons

Activities that may have impact on the environment	During construction				During facility operation											
	Construction activities				Occupation of spaces				Facility operation							
Negative or Positive impact	Negative				Negative				Positive				Negative			
Alternative No.	1	2A	2B	2C	1	2A	2B	2C	1	2A	2B	2C	1	2A	2B	2C
Social Environment																
1. Transportation/public facility	x	xx	xx	xx	xxx	–	–	–	–	–	–	–	–	–	–	–
2. Agriculture/water use	–	–	–	–	–	x	x	xx	xxx	xxx	xxx	xxx	–	–	–	–
3. Public health/sanitation	–	–	–	–	–	–	–	–	xxx	xxx	xxx	xxx	–	–	–	–
4. Solid waste	–	–	–	–	–	–	–	–	–	–	–	–	xx	xx	xx	xx
Natural Environment																
1. Stream flow	–	–	–	–	x	xx	xx	xx	–	–	–	–	–	–	–	–
2. Plants/animals	–	–	–	–	–	x	x	xx	–	–	–	–	–	–	–	–
3. Landscape	–	–	–	–	xx	x	x	x	–	–	–	–	–	–	–	–
Pollution																
1. Water pollution	–	–	–	–	–	–	–	–	xxx	xxx	xxx	xxx	–	–	–	–
2. Noise/vibration	x	x	x	x	–	–	–	–	–	–	–	–	–	–	–	–
3. Odors	–	–	–	–	–	–	–	–	xxx	xxx	xxx	xxx	xx	–	–	–

Note: xxx : Significant impact xx : Some extent of impact x : Small impact
– : No impact

4) Solid Waste

New wastes in the form of sewage sludge will be generated through operation of wastewater treatment facilities in all four alternatives. This sludge must be disposed of at a certain place, or places to be determined.

(2) Natural Environment

1) Stream Flow

The water intake facilities in the Choqueyapu river in all four alternatives may be a potential obstacle to the smooth flow of the river at times of flood.

In addition, the three Lipari alternatives include a section of the main sewer interceptor under the river bed for several kilometers and reductions of the river sections at the plant site(s). These reduced sections may also be potential obstacles to flood flows.

These structures must be given adequate attention and maintained properly so as not to present undo obstacles.

2) Plants/Animals

The three Lipari alternatives transform the green area(s), i.e., the farmland(s) into treatment plant areas by abolishing trees, thereby changing the area(s) and making them less favorable to certain wild life such as birds. The impact is greater in the alternative 2C since it requires a larger area.

3) Landscape

The presence of the treatment plant will constitute a rather negative impact on the landscape. This negative impact would be greater in the Irpavi alternative since the area in the vicinity of the site is much more populated than the area around Lipari.

(3) Pollution

1) Water Pollution

All four alternatives are aimed at the mitigation of the river water pollution. There will be a significant degree of improvement.

2) Noise/Vibration

A certain degree of noise and vibration would be caused during the construction period in all four alternatives. However, these would be temporary phenomena.

3) Odors

All four alternatives would contribute significantly to reduce obnoxious odors presently experienced along the rivers particularly in the South zone of the City.

However, in the Irpavi alternative, handling of the sludge generated in the treatment plant would present some odor problems to the many inhabitants near the sedimentation basins and sludge storage basins.

5.3.5 Economic Evaluation

(1) Basic Points of Economic Evaluation

In estimating the economic cost and benefit, the economic values were estimated under the following conditions and assumptions for every alternatives for basic plan.

1) For economic evaluation activities, the basic price level for cost and benefit estimates was set as of June, 1992. Foreign exchange rate was set at Bs.3.86 to US$1.00 in accordance with the official exchange rate at that time.

2) The opportunity cost of capital represents the economic rate of return for development projects. In Bolivia, this opportunity cost of capital is estimated at 10% which was applied as a discount rate for assessing the economic viability of proposed projects.

3) In the economic analysis, all goods and service applied in the project costs and benefits are estimated on the basis of real economic value. In terms of non-tradable goods and services in local market, the following points must to be considered in the case of converting their financial values to economic one: (a) internal transfer payment and (b) shadow wage of unskilled labour in particular, taking unemployment and underemployment conditions into account. On the other hand, the tradable goods and services are estimated based on the international market prices, so they reflect real economic values. In this report, economic values were estimated to be 90% of total financial values of both the local and foreign portions.

4) Total benefit increases in proportion to the growth of household income and the population up to the year 2010. Beyond 2010, however, it was assumed to be constant.

5) Land acquisition costs were eliminated because (a) it is difficult to determine the economic value of land and (b) the economic value of land in the "without project" condition will be sufficiently offset by the incremental economic value of land in the "with project" condition.

6) The economic life of the projects was taken as 30 years after completion of construction works.

(2) Economic Costs

1) Financial Costs of Alternatives

The construction costs and O&M costs of the alternatives for the basic plan were summarized as follows in financial terms, which were estimated in Section 5.3.1 in detail.

(US$ million, 1992 Prices)

Cost	Alternatives			
	1	2A	2B	2C
Construction Cost	90.59	82.00	76.64	46.03
Annual O&M Cost	5.00	5.00	2.50	3.50

2) Economic Costs of Alternatives

Considering the above conditions and assumptions for conversion of financial cost to economic cost, the economic costs were calculated as follows:

(US$ million, 1992 Prices)

Cost	Alternatives			
	1	2A	2B	2C
Construction Cost	66.52	71.15	66.33	36.62
Annual O&M Cost	4.50	4.50	2.25	3.15

(3) Economic Benefits

A questionnaire survey was carried out in this study to determine how much the people in the study area are willing to pay for receiving direct services from sewerage facilities. This willingness to pay for services is considered to reflect their desire regarding environmental living conditions. It also is a convincing factor to convert their desire to monetary terms. The number of questionnaires reached 976 households, broken down as 898 general residents and 78 apartment residents. As analyzed in Section 2.2.6, the relation between household income and willingness to pay is summarized as follows:

$$y = 1.740 + 0.00137x$$

where,

y : Monthly household income
x : Willingness to pay for purification of rivers

Economic benefit is estimated on the basis of the following procedures and preconditions:

1) The total population projected in Section 3.4.1 was applied.

2) Family size in the study area was 4.47 in 1992. In the future, this size was assumed to be constant in the study area.

3) Household income in the future was assumed to be proportional to the growth of GRDP per capita in La Paz Department. The average household income was Bs.9,156 (equivalent to US$2,409) per annum, according to the questionnaire survey.

4) An economic benefit in the future was estimated by applying the above equation and the estimated future household income.

5) The willingness to pay of major urban facilities such as factories, hotels, commercial buildings and public establishments was assumed to be 30% of that of residents in the study area.

As a result, the economic benefit of basic plan is as shown in Table 5.3.8. The total benefit is summarized as follows: US$1,718 thousand in 1992, US$2,135 thousand in 2000 and US$2,629 thousand in 2010. These benefits show the matured benefits, i.e., the benefits under expected effects accruing from the complete facilities. However, until the completion of the works, only the partial benefit could be expected.

(4) Economic Evaluation

The economic evaluation for respective alternatives was made using several economic indicators: Net Present Value (NPV), Benefit-Cost Ratio (B/C) and Economic Internal Rate of Return (EIRR). As shown above, however, the quantified economic benefits in the future are quite small as compared with the costs. For instance, even in 2010 the matured benefit are estimated at US$2.63 million per year.

From the economic point of view, Alternative 2C is the most economical alternative. The economic cost and benefit stream was calculated in Table 5.3.9. As shown in the table, NPV discounted at 10% was negative US$29.4 million and B/C was 0.32. EIRR also worked out to be negative. Thus, due to the difficulties in quantifing environmental benefits the basic plan was determined not to be feasible from the economic point of view. The project should be considered and justified on the basis of basic human needs with regard to environmental conditions.

Table 5.3.8 ECONOMIC BENEFIT OF BASIC PLAN

Item	1976	1988	1992	2000	2010
1. Population					
Bolivia	4,613,486	6,020,000	6,578,379	8,583,931	10,715,002
La Paz Department	1,465,078	1,926,200	2,110,158	2,774,314	3,484,893
La Paz City	538,597	669,398	719,711	894,496	1,072,166
Study Area			721,506	896,727	1,074,841
2. Households					
Bolivia	1,040,704	1,318,900	1,441,233	1,880,622	2,347,511
La Paz Department	358,065	448,800	491,662	646,408	811,972
La Paz City	129,934	149,754	161,010	200,112	239,859
Study Area			161,411	200,611	240,457
3. Family Size (Assumption: at Constant beyond 1991)					
Bolivia	4.43	4.56	4.56	4.56	4.56
La Paz Department	4.09	4.29	4.29	4.29	4.29
La Paz City	4.15	4.47	4.47	4.47	4.47
Study Area			4.47	4.47	4.47
Project Area			5.64		
4. GDP/GRDP at Market Prices (US$ million at 1991 Constatnt Prices)					
Bolivia	2,041	4,980	6,035	9,284	14,734
La Paz Department	600	1,459	1,669	2,194	2,945
5. GDP (GRDP) per Capita (US$ at 1991 Constant Prices)					
Bolivia	442	827	917	1,082	1,375
La Paz Department	410	758	791	791	845
6. Household Income (US$/Household/year at 1991 Constant Prices)					
Bolivia	1,569	3,021	3,350	3,949	5,021
La Paz Department	1,341	2,601	2,716	2,716	2,901
Project Area(Survey) (Bs./year)			9,156		
Project Area(Survey) (US$/year)			2,409		
7. Willingness to Pay Y(annual value)=(1.740+0.00137X)*12 <===Benefit at Financial Terms					
Project Area(Survey) (US$/Household/year)			8.8		
La Paz Dept. (US$/Household/year)			9.3	9.3	9.5
La Paz Dept. (US$/capita/year)			2.0	2.0	2.1
			|	|	|
Benefit (Total Value in Study Area) (Unit: US$1000 at 1991 Constant)			1,468	1,825	2,247
8. Economic Benefit (Unit: US$1000) *1					
Benefit through Residents			1,321	1,642	2,022
Benefit through Urban Facilities *2			396	493	607
Total Benefit			1,718	2,135	2,629

Note: *1 Standard Conversion Factor: 0.90

*2 Assumed to be 30% of the benefit through residents.

Table 5.3.9 ECONOMIC COST AND BENEFIT STREAM OF ALTERNATIVE PLAN 2C

(Unit:US$ 1000)

No.	Year	Cost			Benefit	Balance
		Construction	O/M	Total		
1	1993	4067	0	4067	0	-4067
2	1994	9264	0	9264	0	-9264
3	1995	9264	0	9264	0	-9264
4	1996	1399	1943	3342	1182	-2160
5	1997	1399	1943	3342	1214	-2128
6	1998	1399	1943	3342	1248	-2094
7	1999	1399	1943	3342	1282	-2060
8	2000	1399	1943	3342	1317	-2025
9	2001	1091	2545	3636	1762	-1874
10	2002	1091	2545	3636	1799	-1837
11	2003	1091	2545	3636	1836	-1800
12	2004	1091	2545	3636	1875	-1761
13	2005	1091	2545	3636	1914	-1722
14	2006	315	3014	3329	2315	-1014
15	2007	315	3014	3329	2364	-965
16	2008	315	3014	3329	2413	-915
17	2009	315	3014	3329	2464	-865
18	2010	315	3014	3329	2516	-813
19	2011	0	3150	3150	2629	-521
20	2012	0	3150	3150	2629	-521
21	2013	0	3150	3150	2629	-521
22	2014	0	3150	3150	2629	-521
23	2015	0	3150	3150	2629	-521
24	2016	0	3150	3150	2629	-521
25	2017	0	3150	3150	2629	-521
26	2018	0	3150	3150	2629	-521
27	2019	0	3150	3150	2629	-521
28	2020	0	3150	3150	2629	-521
29	2021	0	3150	3150	2629	-521
30	2022	0	3150	3150	2629	-521
31	2023	0	3150	3150	2629	-521
32	2024	0	3150	3150	2629	-521
33	2025	0	3150	3150	2629	-521
34	2026	0	3150	3150	2629	-521
35	2027	0	3150	3150	2629	-521
36	2028	0	3150	3150	2629	-521
37	2029	0	3150	3150	2629	-521
38	2030	0	3150	3150	2629	-521
39	2031	0	3150	3150	2629	-521
40	2032	0	3150	3150	2629	-521
41	2033	0	3150	3150	2629	-521
42	2034	0	3150	3150	2629	-521
43	2035	0	3150	3150	2629	-521
44	2036	0	3150	3150	2629	-521
45	2037	0	3150	3150	2629	-521
46	2038	0	3150	3150	2629	-521
47	2039	0	3150	3150	2629	-521
48	2040	0	3150	3150	2629	-521

Present Value

Cost (US$1000)	43258	NPV (US$1000):	-29386
Benefit(US$100	13872	B/C :	0.32
		IRR :	- - -

5.3.6 Overall Evaluation and Selection of an Alternative for the Basic Plan

Evaluation of the four alternatives from various aspects described earlier are summarized in Table 5.3.10.

TABLE 5.3.10 SUMMARY OF EVALUATION OF THE BASIC PLAN ALTERNATIVES

Alternative No.	1	2A	2B	2C
Plant Site	Irpavi	Lipari	Lipari	Lipari
Treatment Method	High rate activated sludge	Conventional activated sludge	Trickling filters	Aerated lagoons
Initial Costs	x	x	x	xxx
Operation Costs	x	x	xxx	xx
Site Availability	x	xxx	xxx	xx
Improvement Effect on River Water Quality	xxx	xx	xx	xx
Technological Adaptability	x	x	xx	xxx
Degree of Environmental Impact	x	xxx	xxx	xx
Degree of Social Impact	x	xxx	xxx	xx

Note xxx : favorable (or easy) xx: average x : not favorable (or difficult)

By referring to Table 5.3.10, Alternatives 2B and 2C are considered to be clearly advantageous over the other two. Closer examination should be made to select from these two alternatives, i.e., 2B and 2C.

The most critical factor governing realization of the plan is considered to be the financial capability to cover the initial and the operational costs. Since the financial resources of the City of La Paz and Bolivia are limited, it is of course considered that the lower the costs, the better the alternative.

From the above considerations, Alternative 2C was selected as the structural component of the Basic Plan for control of water pollution of the rivers in the City of La Paz.

5.4. BASIC PLAN

The basic plan comprises structural and non-structural measures . The structural measures are those included in Alternative 2C which has been selected as described in the previous section. Their details, necessary non-structural measures, effects on water quality improvement, an implementation program, project costs, and financial evaluation for the basic plan are presented hereinafter.

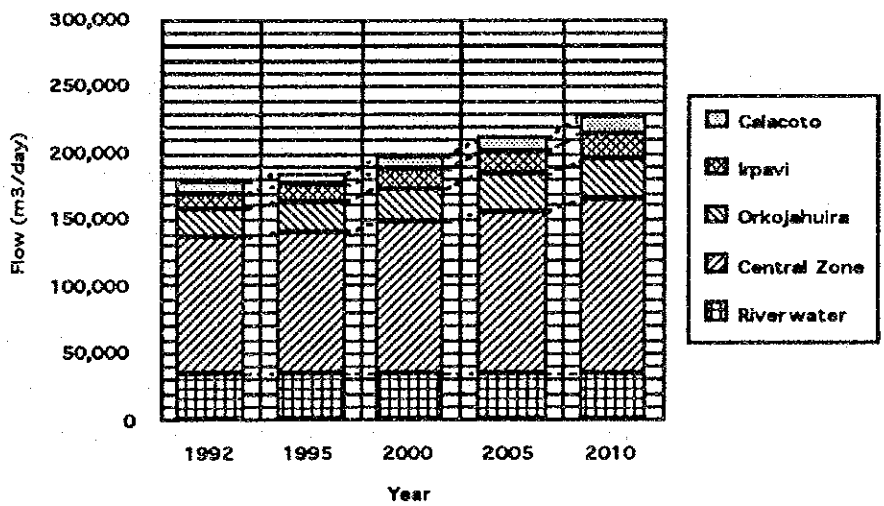
5.4.1 Wastewater Flows

Wastewater flows for the basic plan were calculated as shown in Table 5.4.1 and the subsequent figure.

TABLE 5.4.1 DESIGN WASTEWATER FLOWS FOR THE BASIC PLAN

(m^3/day)

	1992	1995	2000	2005	2010
River water	34,560	34,560	34,560	34,560	34,560
Central Zone	102,609	106,442	113,049	121,359	130,103
Orkojahuira	21,646	23,198	25,920	28,308	30,948
Irpavi	11,223	12,018	13,497	16,622	20,027
Calacoto	8,318	8,667	9,335	10,938	12,728
Total	178,356	184,885	196,361	211,787	228,366



DESIGN WASTEWATER FLOWS BY SEWER COLLECTION ZONES

Note: Not all of these flows would be collected and transmitted to the WWTP until the final stage; see Implementation Program.

5.4.2 Structural Components of the Basic Plan

The structural components of the basic plan are as follows:

- Water intake facilities;	to divert wastewater from the Choqueyapu River to the main sewer interceptor.
- Main Sewer Interceptor;	to transmit wastewater to the wastewater treatment plant.
- Sewer Interceptors;	to collect wastewaters from the existing sewer collection systems and transmit them to the main sewer interceptor.
- Wastewater Treatment Plant;	to treat collected wastewater by means of aerated lagoons and sedimentation basins.

Layout of these facilities are shown in Fig. 5.4.1 and the details of preliminary design of each facility are presented in Appendix-D. Descriptions of each facility are summarized as follows:

(1) Water intake facilities

Water intake facilities are to be installed in the Choqueyapu River at Kantutani, upstream of the confluence with the Orkojahuira River, to collect the wastewater from the central area, where separate sewage collection by sewer interceptors is considered to be difficult.

The Choqueyapu River at the water intake facilities would consist of the wastewater from the central area and river water from upstream. It is proposed to install a water intake weir of a type that diverts a fixed amount of water to avoid an increase of wastewater to the treatment plant in the rainy season.

(2) Main sewer interceptor

The proposed route of a main sewer interceptor is shown in Fig. 5.4.2. The size of the interceptor has tentatively been determined to be 2000 x 2000 mm, based on the provisionally prepared longitudinal profile of the route shown in Fig. 5.4.3 and the design daily maximum wastewater flow of 347,700m^3/day; 150% of the daily average shown in Table 5.4.1.

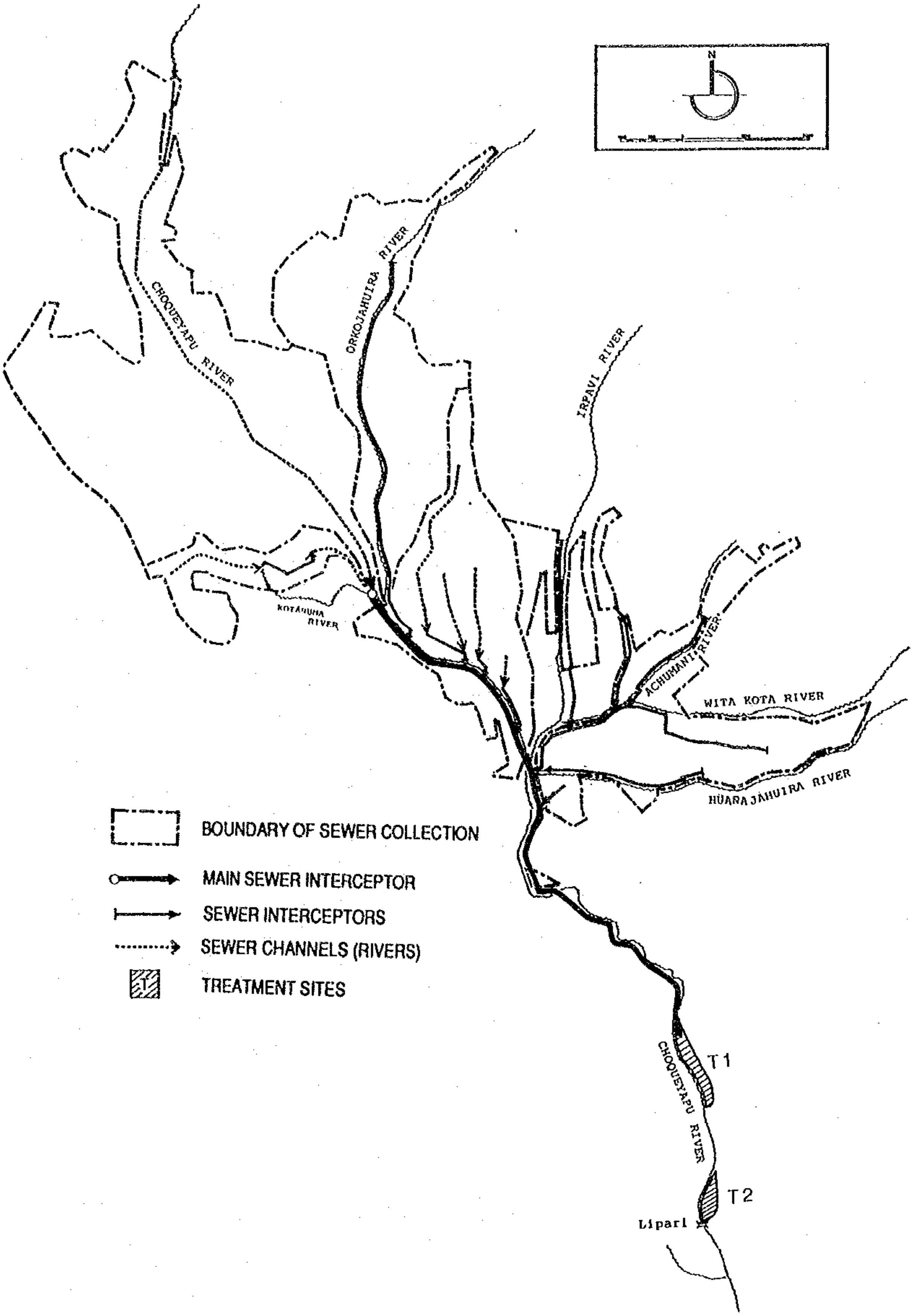


Fig. 5.4.1 GENERAL LOCATION OF THE BASIC PLAN

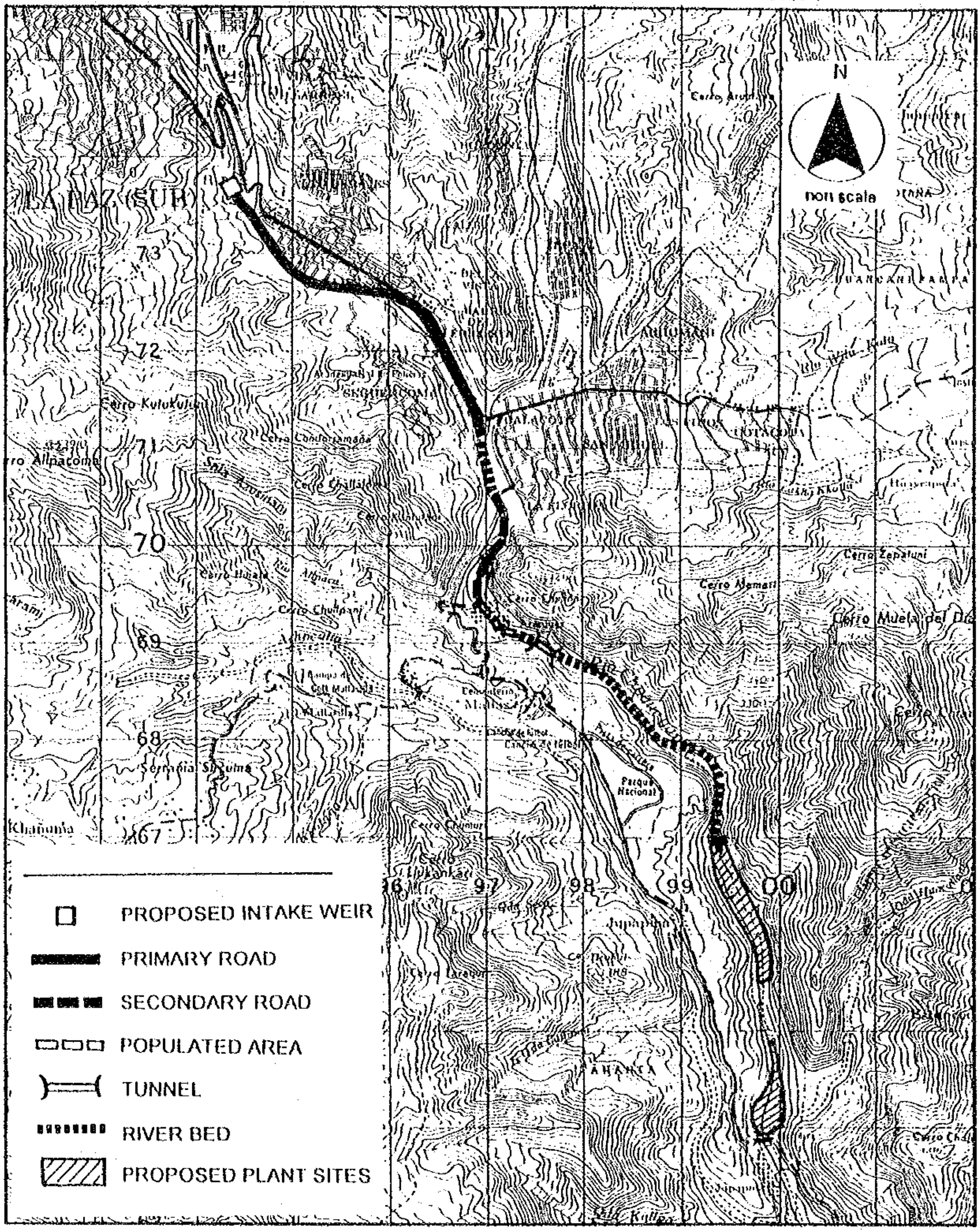


Fig. 5.4.2 ROUTE OF MAIN SEWER INTERCEPTOR

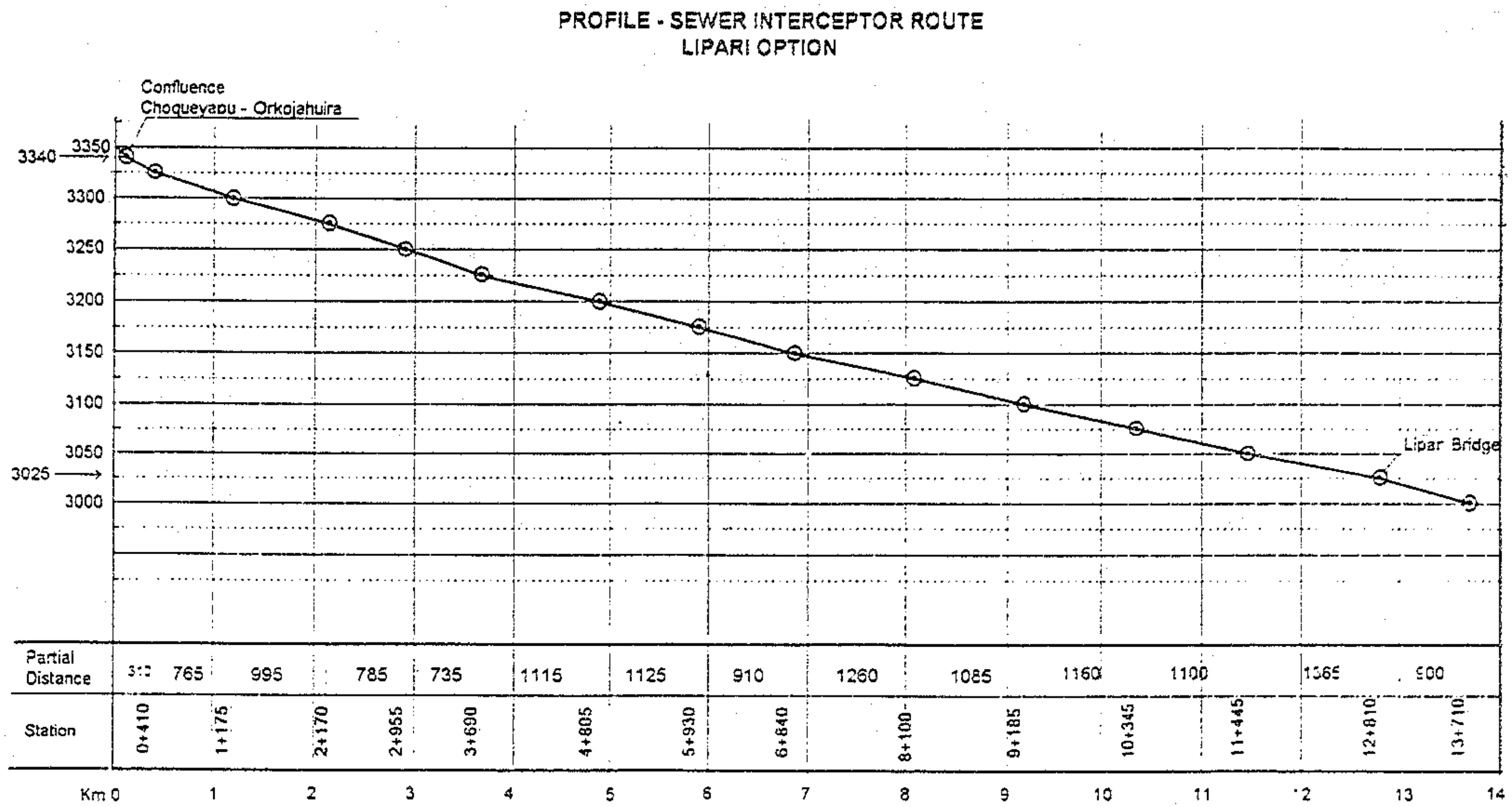


Fig. 5.4.3 Longitudinal Profile of Main Sewer Interceptor (Provisional)

The route of the interceptor is divided into the following sections:

Along main roads (with asphalt pavement)	3630 m
Along secondary roads (with stone pavement)	1260 m
Passing through populated areas	485 m
Tunnel	260 m
In river bed (including gabion protection)	4215 m

The proposed cross sections of the interceptor and the proposed tunnel are shown in Figures 5.4.4 to 5.4.6.

(3) Wastewater treatment plant

Site preparation:	Filling river bed and cultivated areas, Site #1 (20 ha) and Site #2 (12 ha), gabion protection, access road, etc.	
Preliminary treatment:	Bar screens,	Bar size; 1 x 5cm
		Spacing; 5 cm
		Slope; 45 ° from vertical
		Velocity ; 0.5 - 0.9 m/sec
		Cleaning; Manual
	Grit Chambers,	Detention time; 0.8 - 1.0 minutes
		Water depth; 0.7 - 1.0 m
		Length; 18.0 m
		Horiz. Velocity; 0.31 - 0.37 m/s
	Flow measuring,	Parshall Flumes
Aerated lagoons:	Type,	Completely mixed by mechanical aerators
	Volume,	690,000 m3
	Surface Area,	16 ha
	Max. Depth,	6.0 m
	Detention time,	3 days

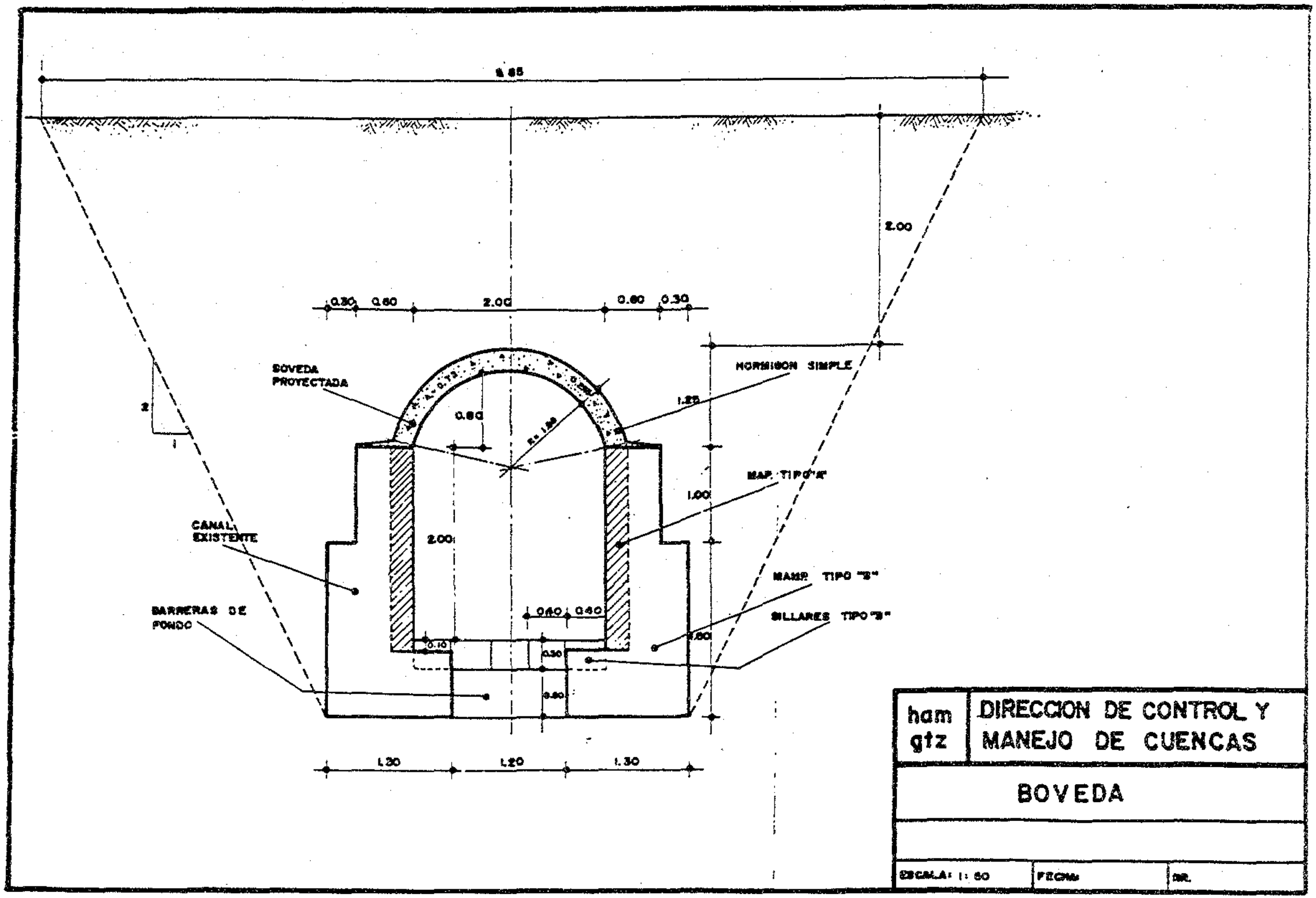


Fig 5.4.4 Typical Cross Section of Main Sewer Interceptor (Roads Section)

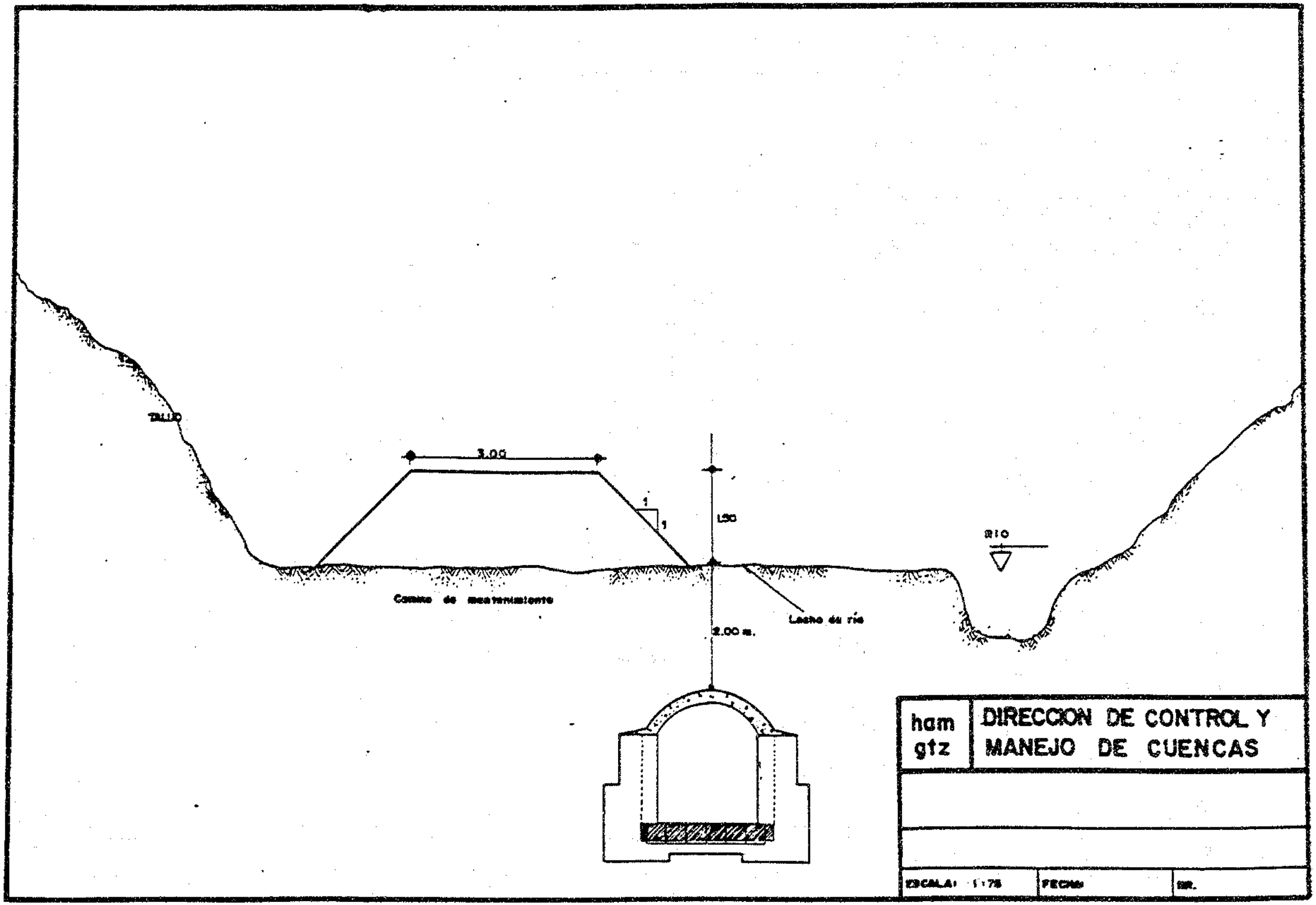


Fig 5.4.5 Typical Cross Section of Main Sewer Interceptor (River Bed Section)

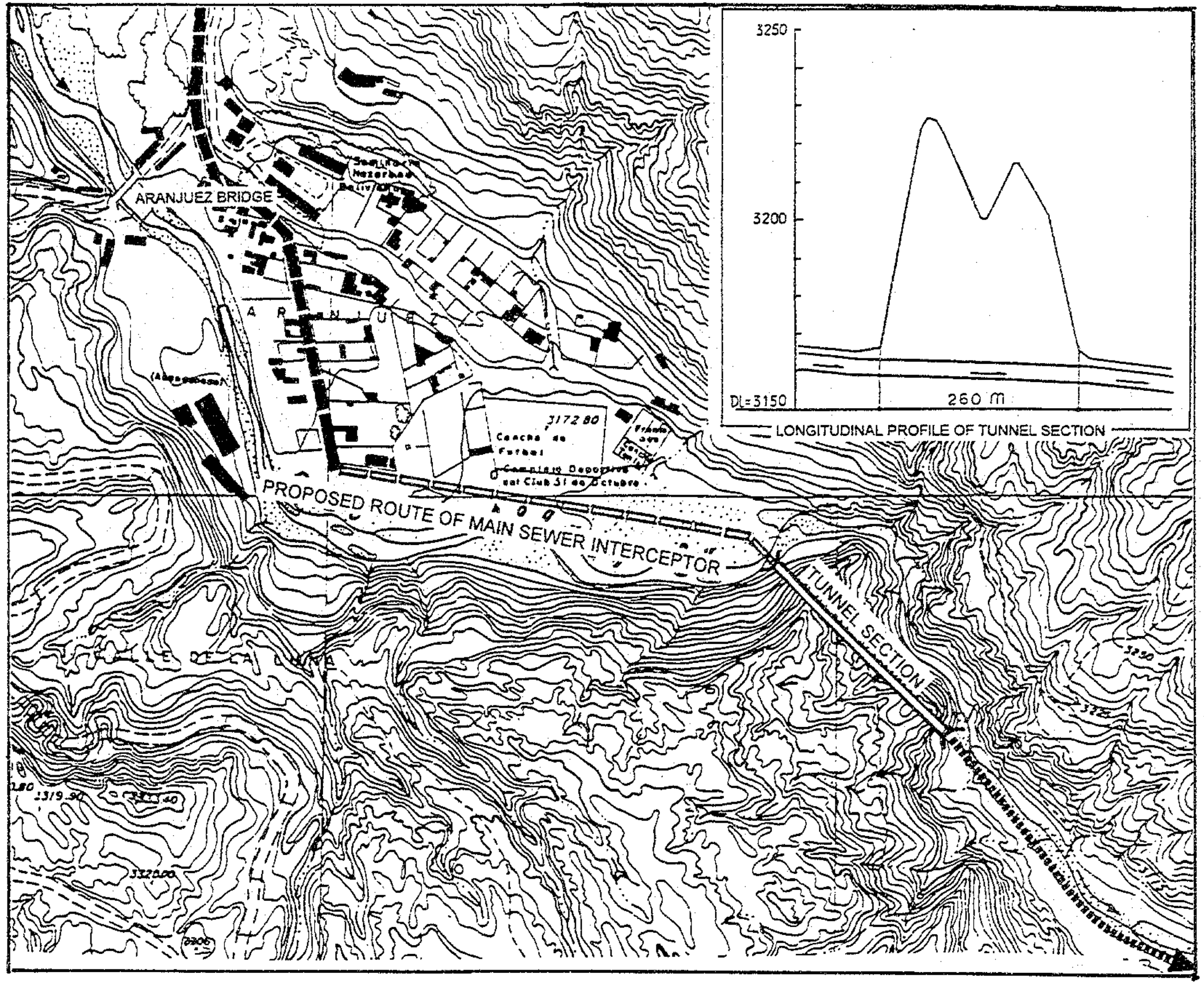


Fig. 5.4.6 Plan and Longitudinal Profile of the Proposed Tunnel for Main Sewer Interceptor

Solids separation basins:	Surface area,	11.5 ha
	Max. Depth,	6.00 m
	Overflow rate,	2 m/day
	Sludge storage,	4 years

5.4.3 Non-structural Measures for the Basic Plan

Implementation of the proposed structural measures for the Basic Plan must be supported by appropriate institutional provisions (non-structural measures). The following measures are particularly important:

a) Reinforcement of existing industrial effluent quality standards

b) Monitoring of industrial effluent discharges and enforcement of the effluent quality standards

c) Monitoring of river water quality

d) Control of solid wastes disposal into the rivers

e) Control of errosion and disorderly extraction of sand and gravel from the river beds

f) Reinforcement of organizations in charge of above tasks and development, operation and management of sewerage works

(1) Reinforcement of Industrial Effluent Quality Standards

"The Regulation on Discharge of Industrial Wastes into Waterbodies" (Ref.K3) in Bolivia sets forth the effluent water quality standards as discussed in Section 2.3.2, and they apply nation-wide. Enforcement of the regulation will undoubtedly contribute to the mitigation of water pollution in Bolivia. However, to implement the proposed sewerage development plan, the Bolivian national standards should be reinforced and partly modified by taking into consideration the particular situations in the City of La Paz. It is proposed that the maximum permissible values of BOD of effluents be modified depending on the location or the source of discharge. The proposed limits are shown in Table 5.4.2.

As shown in Table 5.4.2, the BOD value of 300 mg/l is adopted for wastewater to be discharged into sewer lines connected to a treatment plant, while the Bolivian standards stipulate the same value for discharges into environmental waterbodies. The Central Zone section of the Choqueyapu River above the proposed water intake point is regarded as a sewer channel since the entire dry-season flow would be intercepted at this point and transferred to the treatment plant.

TABLE 5.4.2 PROPOSED LIMITS FOR EFFLUENT BOD

Area	BOD (mg/l)
Choqueyapu River basin in the Central Zone of the City above the wastewater intake point	300
Other areas where wastewater is discharged into sewer lines connected to a treatment plant	300
Newly developing area (*)	50
Other wastewater including treatment plant effluents	50

(*) : Includes domestic and industrial wastewater. Wastewater treatment to be required either as a community or independently.

The BOD value of treatment plant effluents to be received by the rivers is specified as 50 mg/l in order to achieve the water quality target in the Basic Plan.

In newly developing areas, each community or each discharger must have its own treatment facility to meet the above requirement.

(2) Monitoring of Effluent Discharge and Enforcement of the Quality Standards

The Bolivian wastewater discharge regulation stipulates procedures for enforcement of the effluent quality standards. The procedures applicable to existing factories under the present regulation are as follows:

1. Registration with the appropriate entity, i.e., SAMAPA in case of the City of La Paz

2. Application for permission to discharge wastewater by submitting the following to the appropriate entity:

   - outline of operation process

   - operational flow diagram showing mass balances of pollutants and raw materials

- results of analyses of related pollutants for at least two wastewater samples taken and analyzed by personnel of an authorized laboratory

3. Issuance of a discharge permit by the appropriate organization, i.e., Ministry of Urban Affairs (MAU), when reported by the appropriate entity that the applicant has satisfied all the requirements of the regulation.

4. The appropriate entity can periodically (not longer than 6-month period) request factories to submit results of a water quality analysis conducted by an authorized laboratory

5. When the appropriate entity has confirmed that a treatment plant of a factory did not satisfy the conditions for the discharge permit, it is to instruct the factory owner to take the necessary measures urgently.

6. When the factory effluent contaminant level exceeds the permitted limit, the factory has to pay a fine. For a second time violation, the fine is increased to three times that for the first time. When violated for the third time, the discharge permit is suspended indefinitely.

The regulation requires that all analyses of the effluent quality be conducted by a laboratory authorized by the appropriate organization. The procedures for the authorization are also provided in the regulation.

As described above, the Bolivian wastewater discharge regulation provides a good basis for enforcement of the effluent water quality standards. However, to ensure industries' compliance with the standards, some reinforcement and clarification concerning the present discharge regulation would be necessary. The following provisions are recommended:

1. Factories should be under obligation to periodically submit monitoring data on quality and quantity of wastewater discharge rather than to submit them on the request of the appropriate entity.

2. The appropriate entity should be given the power to conduct spot inspections of wastewater treatment and discharge facilities in the factories without prior notice.

3. The regulation should be strictly enforced for factories discharging large amount of wastewater, e.g., over 750 m3/month.

(3) Monitoring of River Water Quality

1) Purposes of Monitoring

The general purposes of environmental water quality monitoring are:

a) To judge the suitability of a waterbody for a desired use by contrasting measured quality against applicable environmental quality standards

b) To obtain basic data for planning pollution control measures necessary to achieve the water quality standards or specific target quality

c) To ascertain the degree of achievement of environmental water quality standards corresponding to the progress of implementing pollution control measures

d) To obtain an indication of the state of compliance of wastewater dischargers with discharge regulations

Water quality surveys of the rivers were conducted in this Study for the purposes of a) and b) above. It is recommended that the City of La Paz establish its own monitoring program to attain all of the above purposes.

2) Monitoring Program

The following program is proposed for the monitoring of river water quality in the City of La Paz.

a) Monitoring station

Fixed monitoring stations should be set up along the Choqueyapu River and its major tributaries. The following points selected from those set up in this Study are proposed:

<u>Choqueyapu River</u>

R2	Achachicala
R4	Ave. Ejercito
R9	Calacoto
R14	Aranjuez bridge
R15	Lipari bridge

Tributaries

R6	Kotauma (downstream end)
R8	Orkojahuira (downstream end)
R11	Irpavi (downstream end)
R12	Achumani (downstream end)

b) Monitoring items and frequency

Item	Frequency
pH, DO, BOD, SS, coliform bacteria, flow rate	Once per month; 12 times per year
As, Cr(VI), Hg	Once each in dry season and wet season at selected stations

Note: Other items specified in the environmental quality standards can be included in the future.

(4) Control of Solid Waste Disposal Into Rivers

Owing to various efforts of the municipal authority, a significant improvement has been made in collection and disposal of domestic solid wastes. The amount of the domestic solid wastes uncollected and dumped into the rivers has been considerably reduced in recent years, and these wastes are considered to contribute little to the organic pollution of the river water as compared to wastewater discharges. However, efforts should be continued to improve the aesthetic conditions of the environment.

On the other hand, industrial solid wastes have not been controlled adequately. Construction wastes are still often dumped into the rivers. These wastes not only disturb the flow of the rivers and urban aesthetics but also aggravate the high level of suspended solids (SS) concentration in the rivers. If such SS-laden water is taken into the sewerage system proposed in the Basic Plan, it will damage the sewer with an accumulation of sediments and disrupt the treatment system. Therefore, dumping of industrial solid wastes into rivers should be strictly controlled from the view points of stream flow protection, urban sanitation, and water quality management. It is recommended that strong administrative measures be taken to stop the dumping of industrial solid wastes.

(5) Control of Erosion and Extraction of Sand and Gravel in the Rivers

Levels of suspended solids (SS) in the Choqueyapu River and its tributaries are generally high. They are particularly high in the Orkojahuira River and the Cotahuma River; the observed SS concentrations ranged from 750 to 1,640 mg/l in the Cotahuma River, and from 2,440 to 6,570 mg/l in the Orkojahuira River at their downstream ends. Because of the inflows from these two tributaries, the SS concentration of the Choqueyapu River increases sharply from approximately 300 mg/l (at R5) to a range of 650 - 1,100 mg/l (at R9).

Since excessively high concentration of SS would disrupt perfomance of the wastewater treatment plant by generating large amount of grit and sludge, the wastewater intake point in the Choqueyapu River should be located above the confluence with the Cotahuma River. As a result, the water quality of the Choqueyapu River below the intake point would be predominantly influenced by the waters of the Cotahuma and Orkajahuira Rivers resulting in a lower concentration of BOD but a much higher concentration of SS. Therefore, it is desirable, from the aesthetic view point, that SS loads from these two tributaries be reduced by taking appropriate measures.

Major causes of the high concentration of SS in these tributaries are considered to be as follows:

1) Fragile soil formation of the basin so as to be eroded easily by natural forces

2) Disorderly extraction of sand and gravel from the river beds

3) Disturbance of the river beds by placer mining activities

Among the above causes, soil erosion is considered to be the greatest, and therefore, appropriate measures for its control should be considered and implemented.

Human activities within the river basins such as 2) and 3) above should be properly regulated.

(6) Organizational Reinforcement

1) Administrative Organs

The major executing organizations of the structural and non-structural measures proposed in the Basic Plan will be the Municipality of La Paz (HAM-LP) and

SAMAPA . Their respective responsibilities and desirable organizational improvements are discussed below.

HAM-LP

HAM-LP's responsibility concerning implementaion of the Basic Plan should cover the following tasks:

a) Preparation of appropriate local rules, regulations and standards concerning water pollution control in coordination with MAU including reinforcement of the effluent water quality standards and designation of waterbodies to specific classes of the environmental water quality standards

b) Water quality monitoring of the rivers

c) Solid wastes management

d) River basin management works including erosion control and regulation of human activities within the river banks

The Bureau of Control and Management of Watershed and Environment (DICOMAC) within HAM-LP should assume the above tasks except solid waste management which is the responsibility of the Bureau of Urban Sanitation (DSU). Since DICOMAC has been mainly engaged in the protection of land rather than protection of water quality, its capacity in water pollution control is limited. It is recommended that DICOMAC reinforce staff capacity in this area.

SAMAPA

SAMAPA's tasks concerning implementation of the Basic Plan includes the following:

a) Sewerage development, operation and management

b) Enforcement of the industrial wastewater discharge regulations

SAMAPA has four management units under the general manager as shown in Fig. 2.3.3, i.e., Management of Engineering and Project (GIP), Management of Operation and Maintenance (GOM), Management of Administration and Finance, and Sales Management. Each management unit has some Departments under which there are some Divisions usually. Development of sewerage is a responsibility of GIP which has the Division of Sewerage Construction but has no Department. Operations and maintenance of sewerage systems are a responsibility of GOM which has the Division of Sewerage Operation but has no Department.

The following organizational reinforcements are proposed:

i) To create the Department of Sewerage Development (DSD) within GIP: DSD to have two divisions, i.e., a division in charge of sewerage planning and design, and a division in charge of sewerage construction.

ii) To create the Department of Operations and Maintenance of Sewerage (DOMS) within GOM: DOMS to have two divisions, i.e., a division dealing with operations and maintenance of sewer lines and a division dealing with operations and maintenance of treatment facilities.

iii) To create a division in charge of enforcement of the industrial wastewater discharge regulation.

2) Water Quality Laboratories

The industrial wastewater discharge regulation requires that sampling and analysis of effluent wastewater be entrusted by factories to MAU-authorized laboratories. Therefore, it is proposed that sampling and analysis of river water in the monitoring program of HAM-LP be also entrusted to these authorized laboratories. Accordingly, availability of laboratories having sufficient capacity in the analyais of wastewater and natural water is very important.

In La Paz, the laboratory of Institute of Sanitary Engineering (IIS) in University of San Andres (UMSA) has been the most experienced in this field. Moreover, most of the analytical equipment brought into La Paz by JICA for this Study were installed in the IIS laboratory, and all the analyses except heavy metals were conducted there by a member of the JICA Study Team in cooperation with the members of the IIS laboratory. Accordingly, IIS's capability in water quality analysis has been further improved.

For the moment, the IIS laboratory is considered to be only the laboratory eligible for the MAU's authorization. It is desirable, however, that there be more than one eligible laboratory, since the demand for water quality analysis should increase as the discharge regulation is enforced and the river water quality monitoring program is implemented. In addition, competition among several laboratories will eventually contribute to technical progress in this sector. In this context, the IIS laboratory may better function as a center for fostering laboratory engineers and analytical specialists in sanitary engineering.

5.4.4 Overall Water Quality Improvement

In Section 5.3.3, the effect of the river water quality improvement by implementation of the proposed sewerage development plan (Lipari option) was evaluated and shown in Fig. 5.3.1, and the effect of industrial wastewater discharge control was also evaluated and shown in Fig. 5.3.2.

As described in Section 5.4.3, the Basic Plan proposes that newly developed areas have their own treatment facilities whose effluent BOD limit be 50 mg/l. The effect of this provision in the year 2010 is shown in Fig. 5.4.7. The figure indicates that the effects below point R9 are considerable.

Fig. 5.4.8 shows the overall effect in the year 2010, in terms of BOD, of the pollution control measures proposed in the Basic Plan. The proposed measures are:

1) Sewerage development including a treatment plant (Lipari option)
2) Wastewater effluent control of the industries discharging over 100 m^3/day of wastewater, with the effluent BOD limit set at 300 mg/l
3) Wastewater effluent control of newly developed area with the effluent BOD limit set at 50 mg/l

The overall effect of the above measures is shown to be significant.

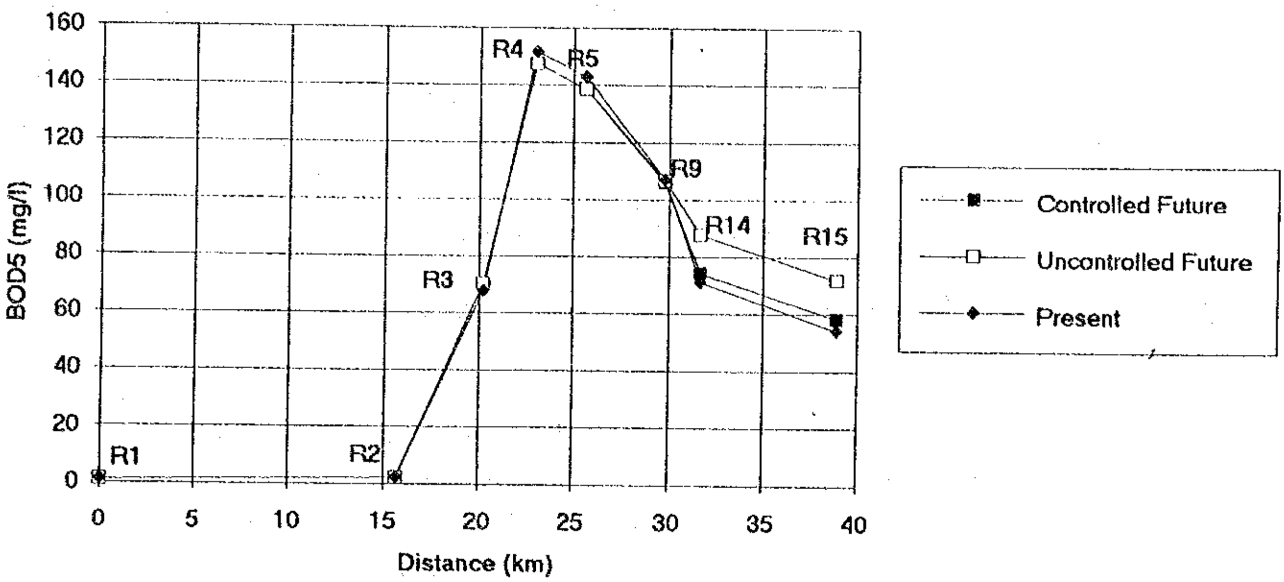


Fig. 5.4.7 Effect of Installation of Community Wastewater Treatment Plant in Newly Developed Areas

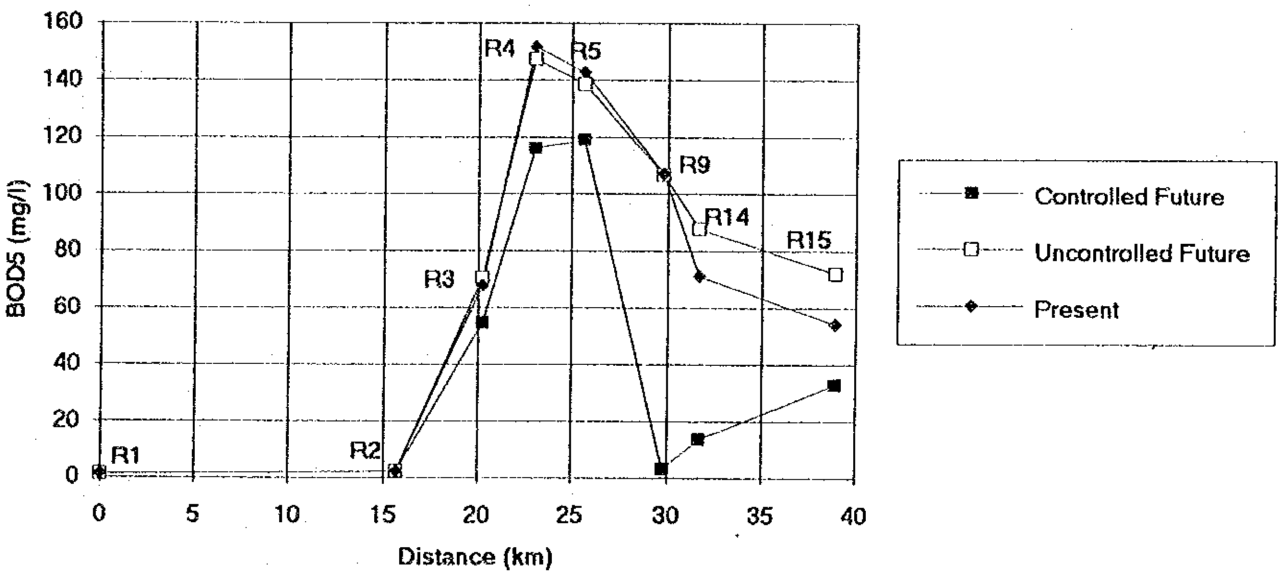


Fig. 5.4.8 Overall Effect of the Basic Plan

5.4.5 Implementation Program

The purpose of the proposed basic plan is to achieve established goals of water quality improvement by the year 2010. Judging from a comparison between the required project costs and budget expenditures relating to the sewerage sector of the central government or SAMAPA, as mentioned in a later section, it is proposed to phase the project so that annual investments during a project period could be as small as practicable. It is also required to phase the project so that benefits of the project could be gained in proportion to the investments.

An implementation program was prepared considering the above requirements, as shown in Table 5.4.3.

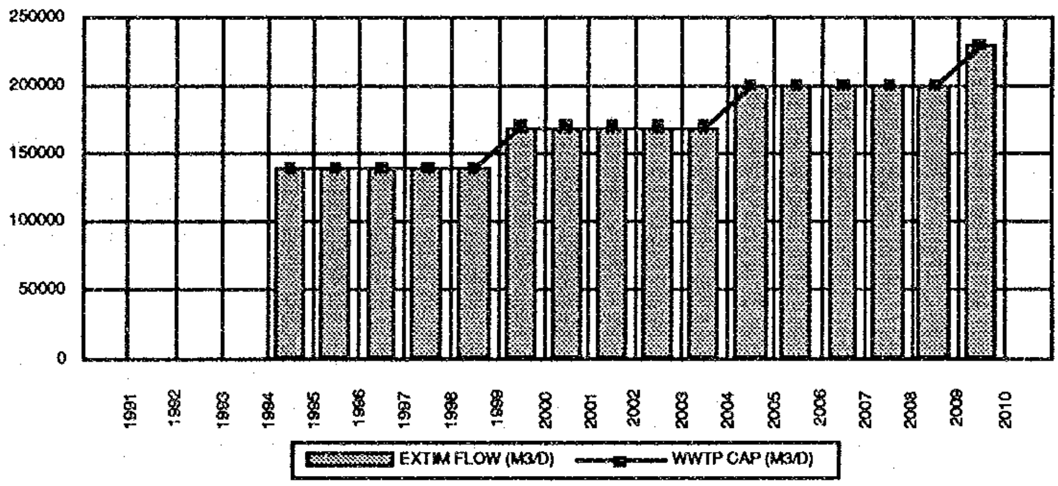
While it is desirable to phase the project in similar stages as mentioned above, major project facility construction is concentrated in the first phase of the proposed project. The reason is that priority should be given to the treatment of wastewater from the central area which is presently the major cause of pollution. Any projects not including some treatment of the wastewater would not contribute significantly to the improvement of the present pollution.

The wastewater treatment capacity and the design wastewater flows for the proposed implementation program are shown in the subsequent figure.

TABLE 5.4.3 IMPLEMENTATION PROGRAM

Implementation Period	Phase	Served areas	Treatment Capacity (m3/d)	Facilities to be Constructed
1993-1995	Phase 1	Central area	140,000 (partial mixed aerated lagoons)	Intake facilities Main sewer interceptor Site preparation - 20 Ha (site #1) Operations/other misc. buildings Aerated lagoons (12 Ha) Sedimentation basins (4 Ha)
1996-2000	Phase 2	Orkojahuira basin	170,000	Conversion of 4 Ha of sed. basins to aerated lagoons Conversion of 12 of partially aerated lagoons to completely mixed lagoons Add aeration equipment Site preparation - 12 Ha (site #2) Sedimentation basins (11.5 Ha) Sewer interceptor for Orkojahuira basin
2001-2005	Phase 3	Irpavi basin	200,000	Add aeration equipment Sewer interceptor for Irpavi basin
2006-2010	Phase 4	Calacoto, etc	230,000	Sewer interceptor for Calacoto area

FLOW VS WWTP CAPACITY



5.4.6 Project Costs

The project costs for the proposed basic plan were estimated more precisely than the previous estimate in Section 5.3.1. The total cost is US$33.32 million, and its breakdown by phase based on the proposed implementation program is shown in Table 5.4.4. In consideration of the phased construction, the required size of the WWTP site was reviewed and reduced to 32 ha from 40 ha, which was estimated in comparison of the Alternatives (Section 5.3.1), resulting in reducing the total construction costs.

TABLE 5.4.4 ESTIMATED PROJECT COSTS FOR EACH PHASE (1992 PRICES)

Phase	Major construction works*	Project costs (million US$)	Costs for each phase (million US$)
1	Water intake facilities	1.15	
	Main sewer interceptor	9.06	
	Wastewater treatment plant (Site #1)	13.62	23.83
2	Sewer interceptor (Orkojakuira basin)	1.92	
	Wastewater treatment plant (expansion to #2)	6.27	8.19
3	Sewer interceptor (Irpavi basin)	0.15	0.15
4	Sewer interceptor (Calacoto area)	1.15	1.15
Total			33.32

* For description of each phase, refer to Table 5.4.3.

5.4.7 Financial Aspects

(1) Financial Aspects

In Bolivia, the capital investment for sewerage systems is basically funded by the public sectors. As discussed in Section 2.2.5, the public entities concerned with the system are: central government, public enterprises, departmental governments and municipal governments.

As regards water pollution control projects, the municipal government of La Paz City (HAM-LP) and SAMAPA are in charge of sewerage system and environmental issues in the Choqueyapu River. For sewerage systems in particular, SAMAPA is the only responsible administrative entity for water supply and sewage treatment in La Paz City. HAM-LP is in charge of maintaining the environment of the rivers in its territories, but only has the power to give administrative guidance to SAMAPA in terms of the sewerage system. Thus, the current sewerage projects would have to be implemented and managed by SAMAPA.

In order to consider the possibility of capital investment for sewerage systems, it is important to figure out the framework and extent of the public budgets. The future trend of public investment for the system was used for estimating the budgetary ceilings of the entities. The past trend of public investment for sewerage systems was summarized in Table 5.4.5. The investment amounts by the major public entities in 1991 were: Bs.67.4 million by the central government; Bs.0.4 million by HAMs in La Paz Department; and Bs.2.1 million by SAMAPA. The future investment ceiling by respective entities was estimated through the following assumptions, referring to the past trend.

1) The budget of the central government was about 11% of GDP, based on the trend during 1986 to 1991.

2) The investment for water, sector by the national government was 4.7% of the national total budget.

3) The total investment for sewerage systems by the respective entities was 50% of the national budget of the water sector. Among those entities, SAMAPA's investment was 4.5% of the total national budget for water sector.

As a result, the capital investment ceilings for the central government are estimated as Bs.181.9 million (equivalent to US$25.4 million) in 2000 and Bs.288.7 million (US$40.3 million) in 2010, and the same for SAMAPA are Bs.8.2 million (US$2.3 million) in 2000 and Bs.13.0 million (US$3.6 million) in 2010. This estimation is broken down in Table 5.4.6.

In addition to local budgets, foreign assistance could be expected for sewerage project, as mentioned in Section 2.3.5. In the past, the following foreign organizations contributed to sewerage projects: IBRD, BID, and Germany (GTZ and KfW) between 1987 and 1991. Multi-lateral assistances, which are supported by IBRD and BID, provide funds mostly through loans. The German government, on the other hand, provides not only loans but also grants. The Japanese government has assisted only for water supply projects and has had no aid experience in sewerage systems in Bolivia.

From the management point of view, it is said to be burdensome for financial status of sewerage system to be kept in a surplus condition. In spite of large investments and comparatively expensive operations, it is difficult to charge beneficiaries for sewage services on the basis of tariffs covering all its costs, that is, a "full recovery policy". To implement sewerage system successfully, it is therefore imperative to procure low-cost funds in addition to fostering the understanding of the beneficiaries.

Table 5.4.5 TREND OF CAPITAL INVESTMENT AND O&M EXPENDITURE BY PUBLIC ENTITIES: 1986-1991

(Unit: Bs.Million)

Item	1986	1987	1988	1989	1990	1991
1 GDP	8,924.0	10,179.0	12,301.0	14,749.0	17,542.0	21,690.0
2 Total Budget of Public Sectors	4,569.4	4,636.1	6,455.4	-	-	-
3 Foreign Assistance	-	-	1,267.6	1,042.2	2,075.7	-
a. Grant	-	-	297.2	163.7	398.2	-
b. Loan	-	-	970.3	878.5	1,677.4	-
4 Central Government						
a. Total Expenditure	966.9	1,056.4	1,297.1	1,567.7	2,034.3	2,725.1
b. Reccurent Expenditure	722.6	892.1	1,097.1	1,342.4	1,711.6	2,374.3
c. Development Expenditure	244.3	164.3	200.0	225.3	322.7	350.8
d. D/Exp. for Water Sector*1	-	4.1	87.4	117.7	131.2	67.4
5 HAM de La Paz						
a. Total Expenditure	23.4	36.1	89.4	61.5	-	123.8
b. Reccurent Expenditure	20.5	23.5	33.8	45.7	-	-
c. Development Expenditure	2.9	12.7	55.6	15.7	-	-
d. D/Exp. for Sewerage *2	-	0.1	0.2	0.2	0.3	0.4
6 SAMAPA						
a. Total Expenditure	-	15.4	20.5	22.5	33.8	32.3
b. Reccurent Expenditure	-	15.4	20.5	22.5	33.8	32.3
c. R/Exp. for Sewerage*3	-	1.5	2.0	2.3	3.4	3.2
d. Capital Investment *4	-	-	11.1	39.7	105.2	53.4
e. C/Invest.*4 for Sewerage	-	0.1	4.3	8.7	5.8	2.1

Note: *1 Including all capital investment for water projects by public sectors.
*2 Including other HAMs.
*3 About 10% of total expenditure, according to the income statement of SAMAPA.
*4 Refer to Table 2.3.21.

Table 5.4.6 PROJECTION OF CAPITAL INVESTMENT FOR SEWERAGE BY PUBLIC ENTITIES AT 1991 CONSTANT PRICES: 1992-2010

(Unit: Bs.Million)

Item	1991	1992	1995	2000	2005	2010
1. GDP *1	21,690.0	22,632.4	26,685.8	34,816.0	44,423.8	55,250.9
2. Central Government						
a. Total Expenditure	2,405.7	2,510.2	2,959.8	3,861.5	4,927.2	6,128.0
b. D/Exp. for Water Sector*2	67.4	118.2	139.4	181.9	232.1	288.7
3. Sewerage by SAMAPA	2.1	5.3	6.3	8.2	10.5	13.0
4. Investment for Water Sector by MAU*3*4						
a. Water Supply	48.4	103.2	121.6	156.3	-	-
b. Sewerage System	18.9	105.6	128.0	172.9	-	-
c. Total	67.4	208.8	249.6	329.2	-	-
5. Investment for Sewerage (US$ Million*4)						
a. SAMAPA	0.6	1.5	1.8	2.3	2.9	3.6
b. Central Government*5	9.4	16.5	19.5	25.4	32.4	40.3
c. Investment Plan by MAU*3	5.3	29.5	35.8	48.3	-	-

Note: *1 Based on Refs.A17 and I4
*2 Including all capital investment for water projects by public sectors.
*3 Refer to Ref.I1.
*4 Exchange rate: Bs.3.58/US$ in 1991
*5 Assumed to be a half of total amount for water sector investment (above 2.b.).

(2) Financial Evaluation

1) Budgetary constraints

The estimated construction costs of the proposed project is US$33.32 million in total, as shown in Table 5.4.7. The investment ceiling amounts by respective entities were also estimated in the same table, in comparison with the estimated project costs.

According to the table, the total ceiling of SAMAPA during the same period, i.e., 1993 to 2010, is estimated at US$45.29 million. The project cost is 74% of the total ceiling. The entire amount of the ceiling would not be available only for the proposed project. Thus, the project could not be implemented without the procurement of funds from external financial organizations. In this report, the total amount to be procured was assumed as follows: 60% of the total by foreign loans and 40% by the local budget. The total amount procured by loans would be US$20.0 million and the local portion would be US$13.3 million.

The total cost is equivalent to 7% of the national investment ceiling for sewerage systems in the country. In the past, the share of SAMAPA to the national total was about 4.5%. Thus, if the entire capital investment for the project is covered by the national finance, the central government would be obliged to make a considerable policy change in terms of environmental issues, in order to implement the proposed project.

2) Cost recovery policy and sewerage service charges

SAMAPA's cost recovery policy for sewerage service is not clear. At present, however, SAMAPA makes all possible efforts to have income cover expenditures in a given year. This endeavour constitutes a "Full recovery policy". Therefore, once the income does not meet the expenditures, SAMAPA would apply MAU and HAM-LP to revise the sewage service tariff.

On the other hand, under the "O&M cost recovery policy" income must cover only the operation and maintenance (O&M) costs. Under this policy, capital costs are customarily covered by the general funds of the governments concerned or by foreign grants.

In the case of a "full recovery policy", the flat sewage service charges are roughly estimated as follows. The entire project costs were estimated at US$33.32

TABLE 5.4.7 CAPITAL INVESTMENT BY PHASE AND INVESTMENT CEILING BY ENTITY

(Unit: US$ Million)

Implementation Schedule	Project Cost	SAMAPA		Central Government	
		Investment Ceiling (*)	Ratio of Project Cost to Ceiling	Investment Ceiling (*)	Ratio of Project Cost to Ceiling
1. Phase 1 (1993-1995) Priority Project Treatment capacity: 140,000 cu.m./day Partial mixed aerated lagoon Served area: Central area	23.83	4.99	477%	55.35	43%
2. Phase 2 (1996-2000) Treatment capacity: 170,000 cu.m./day Served area: Orkojahuira basin	8.19	10.33	79%	114.53	7%
3. Phase 3 (2001-2005) Treatment capacity: 200,000 cu.m./day Served area: Irpavi basin	0.15	13.29	1%	147.38	0.1%
4. Phase 4 (2006-2010) Treatment capacity: 230,000 cu.m./day Served area: Calacoto, etc.	1.15	16.69	7%	185.10	0.6%
5. Total	33.32	45.29	74%	502.37	7%

Note: (*) The ceiling amounts for the respective phase periods were estimated based on the investment projection shown in Table 5.4.6.

million. This total capital cost was annualized through a capital recovery factor (α), that is,

$$A = P \bullet \alpha = P \bullet \frac{i \bullet (1+i)^n}{(1+i)^n - 1}$$

where,

A : Annualized cost,

P : Capital cost,

i : Interest rate (discount rate), 10%,

n : Recovering period, 30 years.

The annualized capital cost was calculated as US$3.54 million, with the factor (α) calculated at 0.10608 on the basis of the above conditions. Then, since the O&M cost is estimated at US$2.70 million per annum, the total annual cost, i.e., the annualized capital cost plus O/M cost, was estimated at US$6.24 million.

The total volume of sewage in the project area in the year 2010 was estimated as about 195,000 m^3/day, or 71.0 million m^3/annum. Then, the average unit cost could be estimated at US$0.088/$m^3$; US$6.24 million divided by 71.0 million m^3.

According to the annual report of SAMAPA in December 1990 (Ref. L4), the average unit charge for water supply and sewage service was Bs.1.06/m^3 or equivalent to US$0.33/$m^3$. According to SAMAPA's financial statements, the sewage charge was 22% of the above charge, so the sewage charge was estimated at US$0.073/$m^3$. The above unit cost was somewhat higher than the present unit charge. Moreover, if this unit cost is recovered by a new tariff, this charge would be added to the present unit charge. Accordingly, the required unit charge would be US$0.161/$m^3$, 2.4 times as much as the present charge of US$0.073/$m^3$.

For the "O&M cost recovery policy", the flat sewage service charges are estimated as follows. As mentioned above, the O&M cost for the basic plan is estimated at US$2.70 million per annum. The total volume of sewage in the project area in 2010 was estimated as about 195,000 m^3/day, or 71.0 million m^3/annum. Then, the average unit cost would be estimated as US$2.70 million divided by 71.0 million m^3 or US$0.038/$m^3$. This would require the service charge of US$0.111/$m^3$, an increase by 52% from the present charge of US$0.073/$m^3$.

3) Procurement of funds and reimbursement schedule

In this section, the following two fund procurement plans are discussed to examine the feasibility of reimbursement by the local budget. The local portion of the capital costs would be covered by public account or procured through a local loan. In this section, the local portion is assumed to be procured through public account. In the case of a grant (Case 2), the total costs including foreign and local portions is considered to be covered by foreign assistance.

a) Case 1: Procurement of foreign loan only

Total amount is procured as follows: US$20.0 million by foreign loans and US$13.3 million by local funds.

<u>Case 1-A</u>

Terms of loan:

- Repayment period: 15 years after completion of construction
- Grace period: 1 year after completion of construction
- Interest rate: 11% per annum

These terms are almost the same as those of the Choqueyapu River canalization project financed by Inter-American Development Bank (BID).

<u>Case 1-B</u>

Terms of loan:

- Repayment period: 30 years after completion of construction
- Grace period: 10 year after completion of construction
- Interest rate: 3% per annum

These terms are almost the same conditions as financed by Overseas Economic Cooperation Fund of Japan (OECF).

b) Case 2: Procurement of grant plus loan

Under this case, only the capital cost of Phase I is covered by foreign grant. Other capital costs of Phase II to IV would be covered by foreign loans of which terms are the same as those of Case 1-A. Thus, the total amount is procured as follows: US$23.8 million by foreign grant, US$5.7 million by foreign loan and US$3.8 million by local funds.

A payment schedule of Case 1, including both reimbursement and interest payment of foreign loan (approximately 60% of the total cost) and procurement of local portion (approximately 40% of the total cost), is tabulated in Table 5.4.8 and 5.4.9. As mentioned above, the local portion was assumed to be procured by local governmental funds. The largest investment by local funds for local portion was US$3.42 million in 1994 and 1995. This amount is about 1.9 times of the expected investment (US$1.8 million, as shown in Table 5.4.6) for sewerage project by SAMAPA in 1995. Thus, even for the local portion only, SAMAPA could not afford to implement this project without assistance of central or municipal governments.

In Case 1-A, the maximum payment occurs in the third year (1995) from the beginning of construction. Its amount will be US$5.00 million, broken down into US$1.57 million for foreign portion and US$3.42 million for local portion. This amount exceeds the annual investment budget of SAMAPA which is estimated at US$1.8 million in the same year, as mentioned above. Thus, the total payment would be about 2.8 times the investment budget of SAMAPA.

In Case 1-B, the maximum payment also occurs in the third year from the beginning of construction. This amount will be US$3.85 million, broken down into US$0.43 million for foreign portion and US$3.42 million for the local portion. This amount also exceeds the annual investment budget of SAMAPA. Thus, the total payment would be about 2.1 times the investment budget of SAMAPA. Thus, even if SAMAPA gets the low interest loan like OECF, it could not implement the proposed project without other assistance.

In Case 2 in Table 5.4.10, the maximum payment would total US$1.20 million in the 8th year (2000) from the beginning of construction. It is broken down to US$0.54 million for foreign portion and US$0.66 million for local portion. In the same year, the annual investment budget of SAMAPA is estimated at US$2.3 million, so the total payment might be lower than the local budget. Thus, if the foreign grant for Phase I portion is available, the scheme of the basic plan could be considered to be feasible from the financial view point.

TABLE 5.4.8 REPAYMENT SCHEDULE OF LOANS: CASE 1-A

(Unit: US$ million)

No.	Year	Phase	Foreign Loan Annual Total	Foreign Loan Accumulation by Phase	Repayment of Foreign Loan Portion and Interest Payment: Phase 1	Phase 2	Phase 3	Phase 4	Total	Local Portion	Total Payment
1	1993	Phase 1	4.02	4.02	0.44				0.44	2.68	3.13
2	1994		5.14	9.16	1.01				1.01	3.42	4.43
3	1995		5.14	14.30	1.57				1.57	3.42	5.00
4	1996	Phase 2	0.98	0.98	1.57	0.11			1.68	0.66	2.34
5	1997		0.98	1.97	2.59	0.22			2.81	0.66	3.47
6	1998		0.98	2.95	2.48	0.32			2.81	0.66	3.46
7	1999		0.98	3.93	2.37	0.43			2.80	0.66	3.46
8	2000		0.98	4.91	2.26	0.54			2.80	0.66	3.45
9	2001	Phase 3	0.02	0.02	2.14	0.54	0.00		2.69	0.01	2.70
10	2002		0.02	0.04	2.03	0.89	0.00		2.93	0.01	2.94
11	2003		0.02	0.05	1.92	0.85	0.01		2.78	0.01	2.79
12	2004		0.02	0.07	1.81	0.81	0.01		2.63	0.01	2.64
13	2005		0.02	0.09	1.70	0.78	0.01		2.48	0.01	2.49
14	2006	Phase 4	0.14	0.14	1.58	0.74	0.01	0.02	2.35	0.09	2.44
15	2007		0.14	0.28	1.47	0.70	0.02	0.03	2.22	0.09	2.31
16	2008		0.14	0.41	1.36	0.66	0.02	0.05	2.08	0.09	2.17
17	2009		0.14	0.55	1.25	0.62	0.01	0.06	1.94	0.09	2.03
18	2010		0.14	0.69	1.13	0.58	0.01	0.08	1.81	0.09	1.90
19	2011					0.54	0.01	0.08	0.63		0.63
20	2012					0.51	0.01	0.13	0.64		0.64
21	2013					0.47	0.01	0.12	0.60		0.60
22	2014					0.43	0.01	0.11	0.55		0.55
23	2015					0.39	0.01	0.11	0.51		0.51
24	2016						0.01	0.10	0.11		0.11
25	2017						0.01	0.10	0.11		0.11
26	2018						0.01	0.09	0.10		0.10
27	2019						0.01	0.09	0.10		0.10
28	2020						0.01	0.08	0.09		0.09
29	2021							0.08	0.08		0.08
30	2022							0.07	0.07		0.07
31	2023							0.07	0.07		0.07
32	2024							0.06	0.06		0.06
33	2025							0.05	0.05		0.05
Total			19.99		30.69	11.13	0.20	1.56	43.59	13.33	56.91

TABLE 5.4.9 REPAYMENT SCHEDULE OF LOANS: CASE 1-B

(Unit: US$ million)

No.	Year	Phase	Foreign Loan Annual Total	Foreign Loan Accumulation by Phase	Repayment of Foreign Loan Portion and Interest Payment: Phase 1	Phase 2	Phase 3	Phase 4	Total	Local Portion	Total Payment
1	1993	Phase 1	4.02	4.02	0.12				0.12	2.68	2.80
2	1994		5.14	9.16	0.27				0.27	3.42	3.70
3	1995		5.14	14.30	0.43				0.43	3.42	3.85
4	1996	Phase 2	0.98	0.98	0.43	0.03			0.46	0.66	1.11
5	1997		0.98	1.97	0.43	0.06			0.49	0.66	1.14
6	1998		0.98	2.95	0.43	0.09			0.52	0.66	1.17
7	1999		0.98	3.93	0.43	0.12			0.55	0.66	1.20
8	2000		0.98	4.91	0.43	0.15			0.58	0.66	1.23
9	2001	Phase 3	0.02	0.02	0.43	0.15	0.00		0.58	0.01	0.59
10	2002		0.02	0.04	0.43	0.15	0.00		0.58	0.01	0.59
11	2003		0.02	0.05	0.43	0.15	0.00		0.58	0.01	0.59
12	2004		0.02	0.07	0.43	0.15	0.00		0.58	0.01	0.59
13	2005		0.02	0.09	0.43	0.15	0.00		0.58	0.01	0.59
14	2006	Phase 4	0.14	0.14	1.12	0.15	0.00	0.00	1.28	0.09	1.37
15	2007		0.14	0.28	1.10	0.15	0.00	0.01	1.26	0.09	1.35
16	2008		0.14	0.41	1.08	0.15	0.00	0.01	1.24	0.09	1.33
17	2009		0.14	0.55	1.06	0.15	0.00	0.02	1.22	0.09	1.32
18	2010		0.14	0.69	1.04	0.15	0.00	0.02	1.21	0.09	1.30
19	2011				1.02	0.39	0.00	0.02	1.42		1.42
20	2012				0.99	0.38	0.00	0.02	1.40		1.40
21	2013				0.97	0.37	0.00	0.02	1.37		1.37
22	2014				0.95	0.36	0.00	0.02	1.34		1.34
23	2015				0.93	0.36	0.00	0.02	1.31		1.31
24	2016				0.91	0.35	0.01	0.02	1.28		1.28
25	2017				0.89	0.34	0.01	0.02	1.26		1.26
26	2018				0.87	0.33	0.01	0.02	1.23		1.23
27	2019				0.84	0.33	0.01	0.02	1.20		1.20
28	2020				0.82	0.32	0.01	0.02	1.17		1.17
29	2021				0.80	0.31	0.01	0.05	1.17		1.17
30	2022				0.78	0.30	0.01	0.05	1.14		1.14
31	2023				0.76	0.30	0.01	0.05	1.11		1.11
32	2024				0.74	0.29	0.01	0.05	1.08		1.08
33	2025				0.71	0.28	0.01	0.05	1.05		1.05
34	2026					0.28	0.01	0.05	0.33		0.33
35	2027					0.27	0.01	0.05	0.32		0.32
36	2028					0.26	0.01	0.05	0.31		0.31
37	2029					0.25	0.01	0.05	0.30		0.30
38	2030					0.25	0.01	0.04	0.30		0.30
39	2031						0.01	0.04	0.05		0.05
40	2032						0.00	0.04	0.05		0.05
41	2033						0.00	0.04	0.05		0.05
42	2034						0.00	0.04	0.05		0.05
43	2035						0.00	0.04	0.04		0.04
44	2036							0.04	0.04		0.04
45	2037							0.04	0.04		0.04
46	2038							0.04	0.04		0.04
47	2039							0.04	0.04		0.04
48	2040							0.03	0.03		0.03
Total			19.99		23.49	8.23	0.15	1.16	33.02	13.33	46.35

TABLE 5.4.10 REPAYMENT SCHEDULE OF LOANS: CASE 2

(Unit: US$ million)

No.	Year	Phase	Foreign Grant and Loan: Grant Annual Total	Foreign Grant and Loan: Loan Annual Total	Foreign Grant and Loan: Loan Accumulation by Phase	Repayment of Foreign Loan Portion and Interest Payment: Phase 1*1	Repayment: Phase 2	Repayment: Phase 3	Repayment: Phase 4	Repayment: Total	Local Portion	Total Payment
1	1993	Phase 1	6.70	0.00	6.70	0.00				0.00		0.00
2	1994		8.57	0.00	15.27	0.00				0.00		0.00
3	1995		8.57	0.00	23.83	0.00				0.00		0.00
4	1996	Phase 2		0.98	0.98		0.11			0.11	0.66	0.76
5	1997			0.98	1.97		0.22			0.22	0.66	0.87
6	1998			0.98	2.95		0.32			0.32	0.66	0.98
7	1999			0.98	3.93		0.43			0.43	0.66	1.09
8	2000			0.98	4.91		0.54			0.54	0.66	1.20
9	2001	Phase 3		0.02	0.02		0.54	0.00		0.54	0.01	0.55
10	2002			0.02	0.04		0.89	0.00		0.90	0.01	0.91
11	2003			0.02	0.05		0.85	0.01		0.86	0.01	0.87
12	2004			0.02	0.07		0.81	0.01		0.82	0.01	0.83
13	2005			0.02	0.09		0.78	0.01		0.79	0.01	0.80
14	2006	Phase 4		0.14	0.14		0.74	0.01	0.02	0.76	0.09	0.85
15	2007			0.14	0.28		0.70	0.02	0.03	0.75	0.09	0.84
16	2008			0.14	0.41		0.66	0.02	0.05	0.72	0.09	0.81
17	2009			0.14	0.55		0.62	0.01	0.06	0.70	0.09	0.79
18	2010			0.14	0.69		0.58	0.01	0.08	0.67	0.09	0.76
19	2011						0.54	0.01	0.08	0.63		0.63
20	2012						0.51	0.01	0.13	0.64		0.64
21	2013						0.47	0.01	0.12	0.60		0.60
22	2014						0.43	0.01	0.11	0.55		0.55
23	2015						0.39	0.01	0.11	0.51		0.51
24	2016							0.01	0.10	0.11		0.11
25	2017							0.01	0.10	0.11		0.11
26	2018							0.01	0.09	0.10		0.10
27	2019							0.01	0.09	0.10		0.10
28	2020							0.01	0.08	0.09		0.09
29	2021								0.08	0.08		0.08
30	2022								0.07	0.07		0.07
31	2023								0.07	0.07		0.07
32	2024								0.06	0.06		0.06
33	2025								0.05	0.05		0.05
	Total		23.83	5.69		0.00	11.13	0.20	1.56	12.90	3.80	16.69

Note: *1 The costs of Phase I are covered by foreign grant.

(3) Household Budget for Sewerage Charge

The household income and expenditure were discussed in Section 2.2.4. On the basis of these present conditions and the following process and assumptions, the household expenditure for sewerage was estimated at US$7.0 in 2010.

a) An annual household income was Bs.9,396 or equivalent to US$2,625 on average in La Paz City, according to Table 2.2.11.

b) This amount was broken down to US$590 per capita, which was equivalent to 75% of GRDP per capita (US$784 as shown in Table 3.4.6) in La Paz Department.

c) If a water expense was assumed to be one-third of water, gas and electricity expenses (2.28% as shown in Table 2.2.11), it would be US$20.0 per annum per household.

d) If 30% of the water expense was assumed to be spend for sewage, a sewage charge would be estimated at US$6.0 or equivalent to 0.228% of the annual household income.

e) According to Table 3.4.6, GRDP per capita was projected to be US$821 in 1995 and US$926 in 2010. Then, the annual household income was estimated at US$2,740 and US$3,090 in the same years.

f) Finally, the total annual amount for sewage by a household was estimated at US$6.2 in 1995 and US$7.0 in 2010.

As described earlier, the sewage service rate might be estimated as US$0.161/$m^3$, in the case of the "full recovery policy". Since the annual discharge of sewage by a household was assumed to be 165 m^3, the annual charge of sewage would amount to US$26.6 in total. This amount is 3.8 times the expected household expenditure for sewerage service of US$7.0 per annum. This case approximately corresponds to the above Case 1-A.

If the capital cost of Phase I is covered by a grant and not included in the depreciable assets, the total capital cost would be US$9.5 million. Then, the annualized capital cost was calculated at US$1.0 million. The total annual cost, that is, the annualized construction cost plus O&M cost (US$2.7 million/year) after completion of the project, was estimated at US$3.7 million. The average unit cost would then be estimated at US$3.7 million divided by 71.0

million m^3 or US$0.052/$m^3$. In this case, since the total sewerage service rate is US$0.125/$m^3$, the annual total charge of sewage would amount to US$20.6, or almost three times the expected expenditure of US$7.0. This case approximately corresponds to the above Case 2.

Incidentally, in the case of the "O&M cost recovery policy", the flat service charge was US$0.111/$m^3$. Then, the annual total charge for sewage service would amount to US$18.3, or 2.6 times the expected expenditure.

Since the required charges to beneficiaries may substantially exceed the regulated tariffs they have to pay, the resulting rates of return represent a minimum estimate rather than a best estimate of the actual rate of return of the project to the economy. In this context, the above charge of US$7.0 may be too small for the best estimate of the actual rate of return. However, this charge accounts for only 26% of the estimated charge of US$26.6 in Case 1-A, and even in Case 2, it accounts for 34% of that (US$20.6). Furthermore, in the case of the "O&M cost recovery policy", it accounts for 38% of the estimated annual charge (US$18.3). Thus, this amount would become a heavy burden for the people in the project area. In the case of continued implementation of the project, careful consideration should be given by the authorities concerned.

(4) Financial Status

To examine the financial status after the implementation of the proposed project, the financial cash stream is made for the above fund cases. The following conditions were assumed to make the streams for every Case:

(a) The management of every case was looked upon as an independence undertaking. Thus, the existing financial income and expenses of SAMAPA were not included in the stream.

(b) Considering the affordability of the people, the sewerage service rates were assumed as US$0.038/$m^3$ (corresponding to US$6.2 per household) in 1995 and US$0.042/$m^3$ (US$7.0 per household) in 2010. Between 1995 and 2010, the rates were set as increasing in proportion to the growth of per capita GRDP. Beyond 2010, the rates were set to be constant.

Table s 4.3.11 to 13 show the financial stream of Case 1-A, Case 1-B and Case 2, respectively. In Cases 1-A and 1-B, the revenue balances were negative for 30 years as seen in the tables. Thus, the rates should be reconsidered to manage the sewerage system soundly. In Case 2, the cash balance was negative only between 1999 and 2007, so the undertaker might have to procure the short borrowing. The total balance for 30 years was US$6.42 million, which could not cover the capital costs of US$23.83 million. This means that the undertaker would have to procure the grant for replacement of the first phase facilities after the economic life of 30 years.

(5) Conclusions

The capital investment for the proposed project might be a burden on SAMAPA's financial management, as discussed in the above section (2). In Case 1-A in particular, the annual payment including reimbursement and interest exceeds the limits of SAMAPA's capability for the annual investment. In Case 2 only, the annual payment is within the limits of SAMAPA's budget capabilities. Thus, SAMAPA should strive for foreign grants.

From the point of view of affordability, the sewage service charge might be a burden on people's budgets, even if the authorities concerned adopt the "O&M cost recovery policy". Thus, to implement the sewerage system successfully, it is most important for the authorities to promote understanding on the part of the beneficiaries as well as to pursue low cost of funds.

Table 5.4.11 STREAM OF INCOME AND EXPENDITURE: CASE 1-A

(Unit: US$ Million)

No.	Year	Capital Balance					Revenue Balance					Cash Balance *1
		Income		Expenditure		Balance	Income	Expenditure			Balance	
		Foreign Loan	Local Portion *1	Construction Cost	Repayment of Loan		Sewerage Treatment Service	M&O Expenses	Depreciation	Interest of Loan		
1	1993	4.02	2.68	6.70		0.00				0.44	-0.44	-0.44
2	1994	5.14	3.42	8.57		0.00				1.01	-1.01	-1.01
3	1995	5.14	3.42	8.57		0.00				1.57	-1.57	-1.57
4	1996	0.98	0.66	1.64		0.00	1.94	1.64	0.79	1.68	-2.18	-1.39
5	1997	0.98	0.66	1.64	1.02	-1.02	1.95	1.64	0.79	1.68	-2.16	-2.39
6	1998	0.98	0.66	1.64	1.02	-1.02	1.97	1.64	0.79	1.67	-2.14	-2.37
7	1999	0.98	0.66	1.64	1.02	-1.02	1.98	1.64	0.79	1.67	-2.12	-2.35
8	2000	0.98	0.66	1.64	1.02	-1.02	2.00	1.64	0.79	1.66	-2.10	-2.33
9	2001	0.02	0.01	0.03	1.02	-1.02	2.45	2.00	1.07	1.55	-2.17	-2.12
10	2002	0.02	0.01	0.03	1.37	-1.37	2.47	2.00	1.07	1.41	-2.00	-2.31
11	2003	0.02	0.01	0.03	1.37	-1.37	2.49	2.00	1.07	1.26	-1.83	-2.14
12	2004	0.02	0.01	0.03	1.37	-1.37	2.51	2.00	1.07	1.11	-1.66	-1.97
13	2005	0.02	0.01	0.03	1.37	-1.37	2.53	2.00	1.07	0.96	-1.49	-1.80
14	2006	0.14	0.09	0.23	1.37	-1.37	3.00	2.35	1.07	0.82	-1.24	-1.54
15	2007	0.14	0.09	0.23	1.38	-1.38	3.02	2.35	1.07	0.69	-1.08	-1.39
16	2008	0.14	0.09	0.23	1.38	-1.38	3.05	2.35	1.07	0.55	-0.92	-1.23
17	2009	0.14	0.09	0.23	1.38	-1.38	3.07	2.35	1.07	0.41	-0.76	-1.07
18	2010	0.14	0.09	0.23	1.38	-1.38	3.10	2.35	1.07	0.28	-0.60	-0.91
19	2011				0.36	-0.36	3.56	2.70	1.11	0.24	-0.49	0.27
20	2012				0.41	-0.41	3.56	2.70	1.11	0.19	-0.44	0.26
21	2013				0.41	-0.41	3.56	2.70	1.11	0.15	-0.40	0.31
22	2014				0.41	-0.41	3.56	2.70	1.11	0.10	-0.35	0.35
23	2015				0.41	-0.41	3.56	2.70	1.11	0.06	-0.31	0.40
24	2016				0.06	-0.06	3.56	2.70	1.11	0.05	-0.30	0.75
25	2017				0.06	-0.06	3.56	2.70	1.11	0.05	-0.29	0.76
26	2018				0.06	-0.06	3.56	2.70	1.11	0.04	-0.29	0.77
27	2019				0.06	-0.06	3.56	2.70	1.11	0.03	-0.28	0.77
28	2020				0.06	-0.06	3.56	2.70	1.11	0.03	-0.28	0.78
29	2021				0.05	-0.05	3.56	2.70	1.11	0.02	-0.27	0.79
30	2022				0.05	-0.05	3.56	2.70	1.11	0.02	-0.27	0.80
31	2023				0.05	-0.05	3.56	2.70	1.11	0.01	-0.26	0.80
32	2024				0.05	-0.05	3.56	2.70	1.11	0.01	-0.25	0.81
33	2025				0.05	-0.05	3.56	2.70	1.11	0.00	-0.25	0.81
	Total	20.00	13.32	33.32	20.00	-20.00	90.94	70.43	31.33	21.40	-32.23	

Note: *1 (Capital balance)+(Revenue balance)+(Depreciation)

Table 5.4.12 STREAM OF INCOME AND EXPENDITURE: CASE 1-B

(Unit: US$ Million)

No.	Year	Capital Balance: Income: Foreign Loan	Capital Balance: Income: Local Portion *1	Capital Balance: Expenditure: Construction Cost	Capital Balance: Expenditure: Repayment of Loan	Capital Balance: Balance	Revenue Balance: Income: Sewerage Treatment Service	Revenue Balance: Expenditure: M&O Expenses	Revenue Balance: Expenditure: Depreciation	Revenue Balance: Expenditure: Interest of Loan	Revenue Balance: Balance	Cash Balance *1
1	1993	4.02	2.68	6.70		0.00				0.12	-0.12	-0.12
2	1994	5.14	3.42	8.57		0.00				0.27	-0.27	-0.27
3	1995	5.14	3.42	8.57		0.00				0.43	-0.43	-0.43
4	1996	0.98	0.66	1.64		0.00	1.94	1.64	0.79	0.46	-0.96	-0.17
5	1997	0.98	0.66	1.64		0.00	1.95	1.64	0.79	0.49	-0.97	-0.18
6	1998	0.98	0.66	1.64		0.00	1.97	1.64	0.79	0.52	-0.99	-0.19
7	1999	0.98	0.66	1.64		0.00	1.98	1.64	0.79	0.55	-1.00	-0.21
8	2000	0.98	0.66	1.64		0.00	2.00	1.64	0.79	0.58	-1.02	-0.22
9	2001	0.02	0.01	0.03		0.00	2.45	2.00	1.07	0.58	-1.19	-0.13
10	2002	0.02	0.01	0.03		0.00	2.47	2.00	1.07	0.58	-1.17	-0.11
11	2003	0.02	0.01	0.03		0.00	2.49	2.00	1.07	0.58	-1.15	-0.09
12	2004	0.02	0.01	0.03		0.00	2.51	2.00	1.07	0.58	-1.13	-0.07
13	2005	0.02	0.01	0.03		0.00	2.53	2.00	1.07	0.58	-1.11	-0.05
14	2006	0.14	0.09	0.23	0.72	-0.72	3.00	2.35	1.07	0.56	-0.98	-0.63
15	2007	0.14	0.09	0.23	0.72	-0.72	3.02	2.35	1.07	0.54	-0.94	-0.59
16	2008	0.14	0.09	0.23	0.72	-0.72	3.05	2.35	1.07	0.53	-0.90	-0.54
17	2009	0.14	0.09	0.23	0.72	-0.72	3.07	2.35	1.07	0.51	-0.86	-0.50
18	2010	0.14	0.09	0.23	0.72	-0.72	3.10	2.35	1.07	0.49	-0.82	-0.46
19	2011				0.96	-0.96	3.56	2.70	1.11	0.46	-0.71	-0.56
20	2012				0.96	-0.96	3.56	2.70	1.11	0.44	-0.68	-0.53
21	2013				0.96	-0.96	3.56	2.70	1.11	0.41	-0.66	-0.51
22	2014				0.96	-0.96	3.56	2.70	1.11	0.38	-0.63	-0.48
23	2015				0.96	-0.96	3.56	2.70	1.11	0.35	-0.60	-0.45
24	2016				0.97	-0.97	3.56	2.70	1.11	0.32	-0.57	-0.42
25	2017				0.97	-0.97	3.56	2.70	1.11	0.29	-0.54	-0.39
26	2018				0.97	-0.97	3.56	2.70	1.11	0.26	-0.51	-0.37
27	2019				0.97	-0.97	3.56	2.70	1.11	0.23	-0.48	-0.34
28	2020				0.97	-0.97	3.56	2.70	1.11	0.20	-0.45	-0.31
29	2021				1.00	-1.00	3.56	2.70	1.11	0.17	-0.42	-0.31
30	2022				1.00	-1.00	3.56	2.70	1.11	0.14	-0.39	-0.28
31	2023				1.00	-1.00	3.56	2.70	1.11	0.11	-0.36	-0.25
32	2024				1.00	-1.00	3.56	2.70	1.11	0.08	-0.33	-0.22
33	2025				1.00	-1.00	3.56	2.70	1.11	0.05	-0.30	-0.19
	Total	20.00	13.32	33.32	18.21	-18.21	90.94	70.43	31.33	12.85	-23.68	

Note: *1 (Capital balance)+(Revenue balance)+(Depreciation)

Table 5.4.13 STREAM OF INCOME AND EXPENDITURE: CASE 2

(Unit: US$ Million)

No.	Year	Capital Balance: Income: Foreign Grant	Capital Balance: Income: Foreign Loan	Capital Balance: Income: Local Portion *1	Capital Balance: Expenditure: Construction Cost	Capital Balance: Expenditure: Repayment of Loan	Capital Balance: Balance	Revenue Balance: Income: Sewerage Treatment Service	Revenue Balance: Expenditure: M&O Expenses	Revenue Balance: Expenditure: Depreciation	Revenue Balance: Expenditure: Interest of Loan	Revenue Balance: Balance	Cash Balance *1
1	1993	6.70			6.70		0.00					0.00	0.00
2	1994	8.57			8.57		0.00					0.00	0.00
3	1995	8.57			8.57		0.00					0.00	0.00
4	1996		0.98	0.66	1.64		0.00	1.94	1.64		0.11	0.18	0.18
5	1997		0.98	0.66	1.64		0.00	1.95	1.64		0.22	0.09	0.09
6	1998		0.98	0.66	1.64		0.00	1.97	1.64		0.32	0.00	0.00
7	1999		0.98	0.66	1.64		0.00	1.98	1.64		0.43	-0.09	-0.09
8	2000		0.98	0.66	1.64		0.00	2.00	1.64		0.54	-0.18	-0.18
9	2001		0.02	0.01	0.03		0.00	2.45	2.00	0.27	0.54	-0.36	-0.09
10	2002		0.02	0.01	0.03	0.35	-0.35	2.47	2.00	0.27	0.51	-0.31	-0.39
11	2003		0.02	0.01	0.03	0.35	-0.35	2.49	2.00	0.27	0.47	-0.25	-0.33
12	2004		0.02	0.01	0.03	0.35	-0.35	2.51	2.00	0.27	0.43	-0.19	-0.27
13	2005		0.02	0.01	0.03	0.35	-0.35	2.53	2.00	0.27	0.40	-0.14	-0.21
14	2006		0.14	0.09	0.23	0.35	-0.35	3.00	2.35	0.28	0.37	0.00	-0.07
15	2007		0.14	0.09	0.23	0.36	-0.36	3.02	2.35	0.28	0.35	0.05	-0.03
16	2008		0.14	0.09	0.23	0.36	-0.36	3.05	2.35	0.28	0.32	0.10	0.02
17	2009		0.14	0.09	0.23	0.36	-0.36	3.07	2.35	0.28	0.30	0.15	0.07
18	2010		0.14	0.09	0.23	0.36	-0.36	3.10	2.35	0.28	0.28	0.20	0.12
19	2011					0.36	-0.36	3.56	2.70	0.32	0.24	0.31	0.27
20	2012					0.41	-0.41	3.56	2.70	0.32	0.19	0.35	0.26
21	2013					0.41	-0.41	3.56	2.70	0.32	0.15	0.40	0.31
22	2014					0.41	-0.41	3.56	2.70	0.32	0.10	0.44	0.35
23	2015					0.41	-0.41	3.56	2.70	0.32	0.06	0.49	0.40
24	2016					0.06	-0.06	3.56	2.70	0.32	0.05	0.49	0.75
25	2017					0.06	-0.06	3.56	2.70	0.32	0.05	0.50	0.76
26	2018					0.06	-0.06	3.56	2.70	0.32	0.04	0.51	0.77
27	2019					0.06	-0.06	3.56	2.70	0.32	0.03	0.51	0.77
28	2020					0.06	-0.06	3.56	2.70	0.32	0.03	0.52	0.78
29	2021					0.05	-0.05	3.56	2.70	0.32	0.02	0.52	0.79
30	2022					0.05	-0.05	3.56	2.70	0.32	0.02	0.53	0.80
31	2023					0.05	-0.05	3.56	2.70	0.32	0.01	0.53	0.80
32	2024					0.05	-0.05	3.56	2.70	0.32	0.01	0.54	0.81
33	2025					0.05	-0.05	3.56	2.70	0.32	0.00	0.55	0.81
	Total	23.83	5.69	3.80	33.32	5.69	-5.69	90.94	70.43	7.50	6.58	6.42	

Note: *1 (Capital balance)+(Revenue balance)+(Depreciation)

5.5 PRIORITY PROJECT

5.5.1 Identification of the Priority Project

In Section 5.4.5, an implementation program for the Basic Plan was proposed, from which the Phase 1 project (up to 1995) in the Basic Plan can be identified as the priority project.

In the priority project, the wastewater from the Central Zone will be collected from the Choqueyapu river and treated at a wastewater treatment plant.

Facilities to be constructed in the priority project are as follows:

- Water intake facilities in the Choqueyapu River (at Kantutani)
- Main sewer interceptor (9.85 km)
- Aerated lagoons (12 ha, 140,000 m^3/day)
- Sedimentation basins (4 ha)
- Operations/miscellaneous buildings

While the treatment plant in the basic plan will occupy two plant sites (#1 and #2), all the treatment facilities for the priority project will be installed at Plant Site #1 (20 ha). The treatment system of the priority project will be composed of partially mixed aerated lagoons and sedimentation basins. In a later phase, all of this system in Site #1 will be converted to completely mixed aerated lagoons and new sedimentation basins will be constructed at Site #2.

5.5.2 Effects of the Priority Project

The water quality improvement effect of the priority project was predicted using the water quality simulation model under the following conditions:

- Dry season flow rate
- BOD removal efficiency of 60% in the proposed plant
- No other measures such as industrial effluent control are taken.

The results are shown in Table 5.5.1 and Fig. 5.5.1. While the BOD would exceed the target value of 50 mg/l in the downstream area if no control measures were to be taken by 1995, the implementation of the priority project would achieve the target BOD value of 50 mg/l; 40 mg/l at R14 and 47 mg/l at R15.

TABLE 5.5.1 IMPROVEMENT OF WATER QUALITY (BOD) BY THE PRIORITY PROJECT (1995)

Evaluation Point	Distance (km)	BOD5 Concentration (mg/l)				
		Results of Simulation		Rate of	Simulated	Rate of
		Controlled Future	Uncontrolled Future	Reduction (%)	Present	Reduction (%)
R1	0	1.2	1.2	0.0	1.2	0.0
R2	16	2.2	2.2	0.0	2.2	0.0
R3	20	68.4	68.4	0.0	67.8	-0.9
R4	23	151.4	151.4	0.0	151.7	0.2
R5	26	142.7	142.7	0.0	143.0	0.2
R9	30	94.6	107.3	11.9	107.1	11.7
R14	32	39.9	73.7	45.8	71.1	43.8
R15	39	47.1	56.9	17.2	54.3	13.3

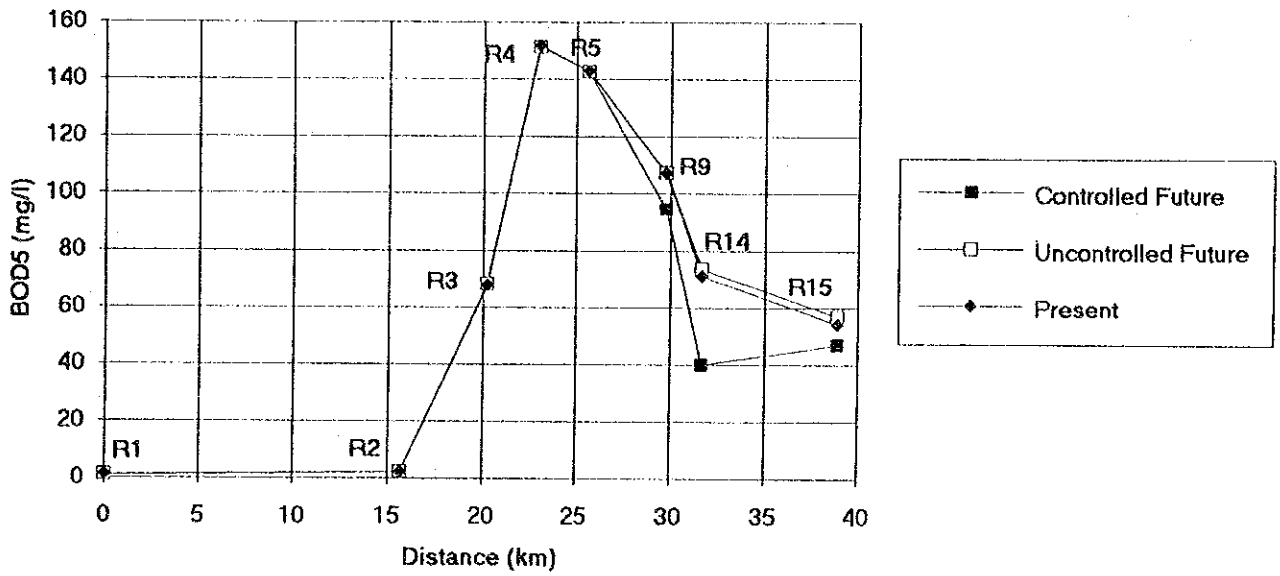


FIG. 5.5.1 IMPROVEMENT OF WATER QUALITY BY THE PRIORITY PROJECT (WITHOUT INDUSTRIAL EFFLUENT CONTROL)

CHAPTER 6
RECOMMENDATIONS - BASIC PLAN

1. Financial Considerations

The proposed basic plan has been developed attempting to keep the initial and operation costs of the required facilities as low as possible. However, the initial cost is roughly equivalent to SAMAPA's investment ceiling which must also cover other sewerage projects including those in El Alto.

On the other hand, the total project cost is equivalent to 7% of the estimated national investment ceiling for the sewerage sector, and the SAMAPA's investment ceiling has been equivalent to only 4.5% of the national ceiling. These figures indicate that it is impracticable to implement the proposed plan by the SAMAPA's financial capacity alone. It may be practicable that the national government extends strong support to SAMAPA by considerably changing the present policy of financing local sewerage development projects. It is recommended that the national government consider this possibility.

2. Integration of Sewerage Development Into Urban Planning

The present water pollution of the rivers in the City of La Paz is, in a large part, a result of lack of a balanced urban development policy. Residential, industrial, commercial, and infrastructural developments have been carried out without a clearly defined environmental conservation policy.

Hence, development of the sewer system has been aimed largely at promotion of the convenience of domestic and social activities rather than protection of the aquatic resources, resulting in the extensive sewer networks but without a wastewater treatment facility.

To achieve real improvement of the quality of life in the urban area, a comprehensive urban reorganization plan should be established, in which the development of the sewerage system with wastewater treatment should be given a high priority.

3. Enforcement of Wastewater Discharge Regulation

The wastewater discharge regulation recently established by the Ministry of Urban Affairs provides a good legal basis to control industrial wastewater discharges. However, some reinforcements of the present regulation are recommended regarding the obligations of industries and the power of regulatory authorities. Even when the regulation is enforced only for the relatively large factories, the amount of pollutants discharge will be significantly reduced. Enforcement of the regulation will require factories to install treatment facilities in order to meet the effluent standards. Since many of the large factories in La Paz City are said to have available space, such installation is technically possible. If not so for some large factories, strong measures including relocation of the factories should be taken.

As regards new residential or other development in the administrative and peripheral areas of the city, all developers should be enforced to install wastewater treatment plants to serve the development areas.

4. Rehabilitation of the Existing Sewerage Facilities

The Basic Plan has been developed based on the concept of utilizing the existing facilities as much as possible to reduce total project cost. Therefore, although there are connections between the sewer lines and storm lines and improper pipe laying, the Plan proposes to use the existing sewer collection systems. Except for the Central Zone, the plan provides overflow weirs on sewer lines to prevent excess inflow to interceptor sewers during storms. However, no provision was possible to include in the plan against sewage inflows into storm lines. If the existing sewer collection systems are left as they are without correcting the existing inter-connections, the effects of the sewage discharges into rivers through storm lines would not be negligible and would reduce the water quality improvement effect of the proposed Basic Plan. Therefor, it is strongly recommended to rehabilitate the existing sewer systems to collect maximum amount of sewage into sewer lines.

5. Organizational Reinforcement

Since the organization for water pollution control in the City of La Paz is not adequate at present, its reinforcement is urgently needed.

The tasks of the Municipality of La Paz, as the responsible body to control water pollution of the rivers, include the following:

- Establishment of local rules, regulations and standards concerning water pollution control in coordination with national authorities

- Water quality monitoring of the rivers

- Control of solid wastes dumping into rivers
- Control of erosion
- Control of disorderly activities in riverbeds
- Promotion of public awareness of water pollution control

To execute the above tasks, the capacities of relevant sections of the Municipality should be strengthened.

SAMAPA is responsible for development, operation and management of sewerage system as well as for enforcement of industrial wastewater discharge regulations. It has a considerable degree of experience in developing sewer pipe networks, but it has no experience in developing large-scale wastewater treatment plants. A considerable degree of reinforcement of the organization of SAMAPA is recommended to execute sewerage development, operations and maintenance.

6. Management of Basic Data

To draw up efficiently a rational plan for control of water pollution in the rivers, reliable basic data are necessary including the following:

- Population and its zonal distribution
- Topographical maps
- Up-dated maps of developed areas
- Hydrological and meteorological data
- Drawings of river courses and river sections

Availability of reliable data concerning the above are limited, and sometimes, the existence of useful data is not known to the persons needing it the most. Some data such as hydrological and meteorological data are not systematically compiled so that they can be utilized efficiently .

The basic data should be compiled and processed, and systems of providing the basic data should be established through cooperation between the relevant authorities.

PART (III)

FEASIBILITY STUDY

CHAPTER 7 DESIGN OF PROJECT FACILITIES

7.1 DESIGN WASTEWATER FLOW

The priority project is to be implemented as the first stage of the Basic Plan. It aims to treat the wastewater from the Central zone, excluding the Orkojahuira basin, by diverting the Choqueyapu River water to the wastewater treatment plant. It is planned to be implemented between 1993 and 1995.

Therefore, the wastewater to be treated in the priority project is the estimated wastewater generation from the Central zone in 1995. However, the capacity of each component of the facilities should be designed as shown below so as to be able to cater to the increased wastewater in later phases:

- Water intake facilities: These facilities will be used in the final phase of the basic plan, without any expansion. Thus it will have the capability to divert the Choqueyapu River low flows in 2010.

- Main sewer interceptor: This sewer will be used in the final phase of the basic plan without any expansion. While the interceptor will transmit only the wastewater from the Central zone from the water intake facilities in the priority project, it will receive all the wastewaters from remaining areas through sub-main sewer interceptors in later phases. Therefore, the capacity of the interceptor is designed based on the total wastewater in the area in 2010.

- Wastewater treatment plant: The wastewater treatment plant has been planned to expand its capacity by phases. It will treat only the wastewater from the Central zone in the priority project and expand its capacity in the later phase according to the increase in the wastewater due to the increase in the areas covered.

Considering the above, design wastewater flows for each component of the Priority Project were determined as follows:

Component	Design wastewater flow	Remarks
Water intake facilities	170,000 m^3/day	River flow (0.4m^3/s) + wastewater generation in the Central zone except the Orkojahuira basin in 2010.
Main sewer interceptor	230,000 m^3/day	Total wastewater generation in the served area in 2010
Wastewater treatment plant	140,000 m^3/day	River flow (0.4m^3/s) + wastewater generation in the Central zone except the Orkojahuira basin in 1995.

7.2 WASTEWATER INTAKE FACILITIES

The purpose of installing intake facilitiec is to collect directly from the Choqueyapu River wastewater generated in the Central zone of the City because interception of the wastewater by sewer pipes before its discharge into the river would be very difficult in the Central zone. The river at the intake weir, which comprises natural river water and the wastewater from the Central Area, is to be diverted to the wastewater treatment plant through the main sewer interceptor. The weir would divert the entire dry-season river flow and let the excess overflow during the rainy season. Also it should not be hazardous to flood discharges.

7.2.1 Determination of the Location

The facilities should be installed downstream of the crossing of the Avenida Libertadores to collect all the wastewater from the Central area, and upstream of the confluence with the Orkojahuira River. The wastewater from the Orkojahuila basin is to be collected by a sub-main sewer interceptor. Between the crossing of the Avenida Libertadores and the confluence with the Orkojahuira River, there is the confluence with the Cotahuma River.

The Cotahuma River and Kantutani River meet at a point about 30 m upstream of the confluence with the Choqueyapu River. The Cotahuma River water contains several thousand mg/l of suspended solids, which is due to the natural soil conditions of the upper stream basin and quarry activities in the river bed. The Kantutani River has a BOD concentration of several hundred mg/l, which originates from the residential area in Sopocachi.

Installing the facilities downstream of the confluence with the Cotahuma River would increase the suspended solid loading to the main sewer interceptor and the treatment plant by about 100 % of the loading from the central area because of its extremely high suspended solids concentration. Consequently, it is proposed to install the weir upstream of the confluence with the Cotahuma River. However, this would not permit collection of the wastewater from Sopocachi through the Kantutani River.

It was therefore decided to collect the Kantutani River water by diverting it from the Cotahuma River. The following two options are considered for this purpose:

i) To install a water intake weir in the Kantutani river before the confluence with the Cotahuma River.

ii) To divert the Kantutani river from its the confluence with the Cotahuma River to the Choqueyapu River.

For the former option, it would be required to construct two water intake weirs in the Choqueyapu River and the Kantutani River, and to operate two weirs. This would cause higher construction and operation costs. Therefore, it is proposed to apply the latter option, to construct a diversion channel from the Kantutani River to the Choqueyapu River, and to construct a water intake weir in the Choqueyapu River at a location 12 m upstream of the confluence with the Kotauma River, as shown in Fig. 7.2.1.

7.2.2 Preliminary Design

The water intake facilities comprise a weir, a sluice gate for flow control, a connecting pipe, an interface chamber to the main sewer interceptor, and miscellaneous works, such as consolidation works for protection of the river bed and stop logs for flushing the sediment from behind the weir. The designed facilities are shown in Fig. 7.2.1 and explanations for each facility are given below:

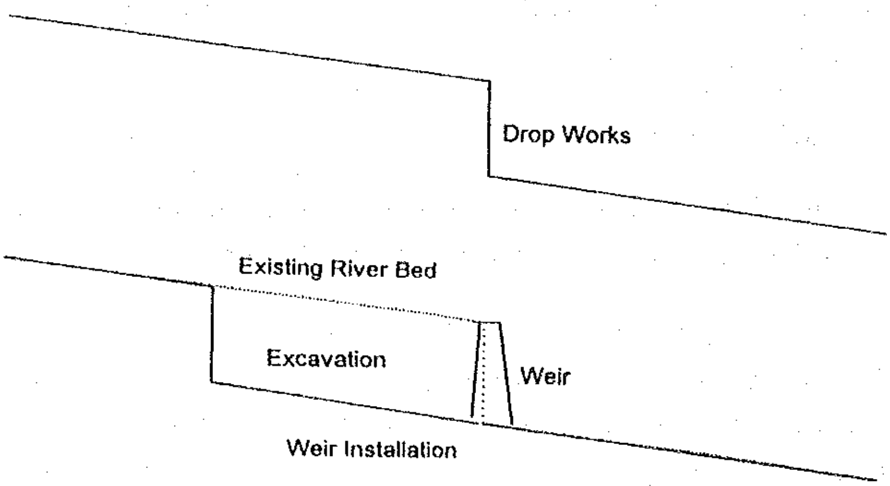
(1) Weir

In designing of the weir, it is most important not to reduce the flood discharge capacity of the river. Accordingly, the weir is designed below the level of the existing river bed by excavating the existing drop structures to provide an impoundment as shown in the following sketch.

The function of the water intake facilities is to divert water at a constant rate under the varying flow conditions. There are two basic ways to maintain the constant diversion rate by gravity flow:

i) By adjusting the weir height manually or automatically to maintain a constant level in the impoundment.

ii) By adjusting the opening of the sluice manually or automatically.



In case of a failure in the operations, the first method would directly affect the discharge capacity of the river, while the latter would affect only the intake rate. In addition, the adjustment of the weir height would require larger scale control equipment which is more costly than that for the sluice control. The proposed weir is of a type with wooden stop logs supported by H beams at both sides. The stop logs are not to be used to control the flow rates but are used to impound the water and would be periodically removed to clean up the impoundment.

(2) Sluice Gate

The sluice gate structure would transfer water from the impoundment to the interface chamber. The opening of the sluice gate is to be adjusted manually to maintain a constant inflow rate independent of the level of impoundment which would increase as the river flow rate increases.

During the dry season, it will be not necessary to control the opening of the sluice gate since the entire river water is to be taken, but it will be necessary to reduce the opening according to the increase of the impoundment level due to increased flow. Therefore monitoring of the level of the impoundment and adjustment of the opening will be required during the rainy season.

The manual control of the gate opening may cause delays in responding to the increase of the impoundment level resulting in excess flow to the main sewer interceptor. However, the duration of such excess flow can be limited to one or two hours by conducting a frequent monitoring of the level of the impoundment or the river flow during rainy periods. The excess wastewater inflow to the wastewater treatment plant in such a short period will not affect the performance of the plant because the plant has such a long detention time on the order of 3 days. The relation between the impoundment level and the opening of the slice gate for inflow control should be studied in the final design stage.

(3) Interface Chamber

The interface chamber will provide a connection between the sluice and the main sewer interceptor. The position of the outlet to the main sewer interceptor will be determined by the level of the bottom of the sluice gate and the level of the main sewer interceptor.

It will have a cover for maintenance work and space for a sand pit below the outlet.

7.2.3 Cost Estimates

The construction costs for the intake facilities are estimated as shown in Table 7.2.1 and summarized as follows:

Civil works	US$49,000
Equipment/materials	US$31,000
Total	US$80,000

TABLE 7.2.1 ESTIMATES OF CONSTRUCTION COSTS FOR WATER INTAKE FACILITIES

Items		Quantity	Unit Price (US$)	Amount (US$)
Civil works				
	Concrete	319 m^3	115	36,685
	Reinforced Concrete	8.5 m^3	139	1,182
	Excavation	433.6 m^3	13	5,637
	Backfill	14.9 m^3	4	60
	Gabion	120 m^3	43	5,160
	subtotal			48,723
Equipment/materials				
	Screen	1	1,385	1,385
	Gate	1	26,538	26,538
	Grating	1	1,385	1,385
	H-beams	2	692	1,385
	subtotal			30,692
Total				79,415

The required works for operating the water intake facilities are as follows:

- Monitoring of the level of the impoundment
- Opening/closing of the sluice gate
- Cleanings

The operating costs for the above works will be estimated as part of those for the main sewer interceptor.

7.3 MAIN SEWER INTERCEPTOR

7.3.1 General

In the priority project, the main sewer interceptor is to be installed to transmit the Choqueyapu River water from the intake point upstream of the Orkojahuira River confluence to the treatment plant site. However, the main sewer interceptor will also collect the wastewater from other basins in the later phases. Thus the main sewer interceptor should be designed for the ultimate wastewater amount. The general layout of the main sewer interceptor is shown in Fig. 7.3.1.

7.3.2 Selection of the Route

(1) Section A

There are two possible routes for the section between the water intake facilities and the Calacoto area, one along the left bank, and the other on the right bank of the Choqueyapu River. The general layout of two routes are shown in Fig. 7.3.2.

As can be seen in the Figure, most of the route of the left bank goes along the trunk road, from the central area to Aranjuez, which always has heavy traffic. The right bank route goes along the right bank of the Choqueyapu River, where road construction is under way.

The left bank route would limit the construction method to installation of the pre-cast concrete pipe and require relatively narrow excavation works due to its heavy traffic conditions. The estimated pipe diameters in this section are 1350 mm and 1500 mm. These pipes must be imported or specially manufactured for this project since these sizes are not available in the local market. On the other hand, in the case of the right bank route, it is considered possible to apply *in situ* arched sewer, which are commonly used in La Paz for the construction of underground channels, because there will be less restriction in the excavation works along this route.

The costs comparison between the two routes, shown in the Table 7.3.1, indicates a higher estimated construction costs for the left bank route than for the right bank route because of the difference in the construction methods mentioned above. In addition, there exist more underground utilities in the left bank route as compared to the right bank route. More difficulties are foreseen in the installation for the left bank route. Consequently, it is decided to select the right bank route for Section A.

TABLE 7.3.1 COST COMPARISON OF ROUTES FOR SECTION A

Route	Work items	Quantity (m)	Unit Price (US$/m)	Amount (US$)	Total (US$)
Left Bank	Aqueduct (1000mm)	20	2,532	50,640	
	PC*-pipe (1200mm)	340	454	154,360	
	PC-pipe (1350mm)	3,570	513	1,831,410	
	PC-pipe (1500mm)	710	576	408,960	2,445,370
Right Bank	PC-pipe (1200mm)	80	454	36,320	
	Arched Masonry(1300mm), unpaved	50	365	18,250	
	Arched Masonry(1300mm), pedst.	710	250	177,500	
	Arched Masonry(1500mm), pedst.	1,120	277	310,240	
	Arched Masonry(1500mm), paved	2,070	473	979,110	
	Arched Masonry(1500mm), river bed	630	535	337,050	
	Access road	130	19	2,470	1,860,940

* Pre-stressed Concrete

(2) Section B

There are two possible routes for this section; a route along the existing road and a route along the river bed. The route along the road is selected because of the following reasons:

- Length of the route along the river bed is longer than that along the road.
- There is no space for pipe installation in the section under the Aranjuez bridge.

(3) Section C

In this section, the route along the road is judged to be impractical because the road runs high above the river level. Thus, the major portion of route selected is in the river bed.

The upper portion of this section passes through the residential area of Aranjuez along the existing road and the route enters the river bed downstream of the residential area. There is a ravine and a sharp meandering of the stream just below the Aranjuez residential area, where there is no space for the pipe installation in the river bed. Therefore, it is proposed to construct a tunnel in this section (about 300m long).

Downstream of this tunnel section to the plant site (about 3000m long), the river has a wide river bed where the interceptor is to be installed.

7.3.3 Design Criteria

In the design of the interceptor, the design standards used by SAMAPA and HAM are applied, considering following conditions:

1) Design Flow

The hourly maximum wastewater flow (150% of the daily maximum) plus the dry season river flow is applied as a design flow for the interceptor.

2) Type of Interceptor

The arched masonry type is generally adopted for the interceptor because of the following reasons:

- Prestressed concrete pipes (PC pipes) with diameter over 1200 mm are not available in the local market.

- The arched masonry type is commonly used for construction works for underground urban drainage in La Paz.

- In the case of PC pipe, if the pipe is installed following the ground surface gradient, it would cause excessive flow velocity due to steep ground condition. To maintain the flow rate within the proper range it would be required to install the pipe with milder gradient than the ground surface and to install drop manholes at short intervals. On the other hand, in the case of the arched masonry type, it is possible to construct it with frequent step-like drops.

In cases where there is limited space for excavation, PC pipe is adopted.

3) Flow Velocity

The flow velocity in the interceptor should be less than 3.5 m/sec.

4) Calculation of Flow Rate and Velocity

These are calculated by the Manning formula:

$$V = (1/n) \cdot R^{2/3} \cdot S^{1/2}$$

and $Q = A \cdot V$

where,
Q: Flow rate (m2/sec)
A: Flow area (m2)
V: Velocity (m/sec)
n: Roughness coefficient
R: Hydraulic radius (A/P)
P Wetted perimeter (m)
S: Gradient

5) Roughness Coefficient

The adopted roughness coefficients are as follows:

Concrete products	0.015
Masonry	wall: 0.022,
	bottom: 0.05

6) Margin of the Flow Capacity

The sizes of the interceptor are determined to provide the following margins above the design flow:

PC-concrete pipes:	less than 450 mm dia.	:	100 %
	500 - 1000 mm	:	50 %
	more than 1100 mm	:	30 %

Arched masonry: 25 %

7) Minimum Earth Cover

Sections under roads: 1.0 m
Sections under river bed: 2.0 m

8) Interval Between Manholes

Manholes are installed at the terminals of the interceptor, changing points of direction and gradient, confluences with sub-interceptors and at following intervals in the straight sections:

Less than 800 mm dia.	70 m
More than 1000 mm dia.	100 m

7.3.4 Preliminary Design of Main Sewer Interceptor

The main sewer interceptor was deigned along the route selected above. The route and the longitudinal profiles are shown in Figs. 7.3.3 and 7.3.4. The sizes of the interceptor for each section were calculated based on the criteria mentioned above and the design wastewater flow rates as shown in Table 7.3.2. Typical cross sections of the arched masonry interceptor including manhole sections are shown in Fig. 7.3.5.

In the section downstream of Aranjuez, the interceptor is to be installed under the river bed. To protect the buried interceptor from exposure by erosion, it is proposed to construct groin works at meandering sections. The location of the groin works and typical structures are shown in Fig. 7.3.6 and Fig. 7.3.7. Also in this section, it is proposed to construct a road in the river bed along the interceptor route for maintenance works.

TABLE 7.3.2 SIZES OF THE INTERCEPTOR

Section	No.	Design Wastewater (m^3/sec)	Size (mm x mm)	Gradient (%)	Velocity (m/sec)	Max. Capacity (m^3/sec)
A	1	2.523	1200 dia	1.0	2.99	3.379
	2	2.523	1300, 1300	2.0	2.33	3.155
	3	2.523	1300, 1300	2.0	2.33	3.155
	4	2.553	1500, 1500	2.0	2.57	4.620
	5	3.066	1500, 1950	2.0	2.57	4.620
	6	3.185	1500, 1950	2.0	2.57	4.620
	7	3.261	1500, 1950	2.0	2.57	4.620
	8	3.299	1500, 1950	2.0	2.57	4.620
	9	3.493	1500, 1950	1.8	2.44	4.383
B	10	3.502	1500, 1950	1.5	2.22	4.001
C	11	3.504	1500, 1950	2.0	2.57	4.620
	12	3.504	1500, 1950	2.0	2.57	4.620
	13	3.504	1500, 1950	3.0	3.14	5.659
	14	3.504	1500, 1500	1.8	3.14	4.383

7.3.5 Cost Estimates

(1) Construction Cost

The construction costs were estimated using unit prices for the various materials, sizes and ground surface conditions. The estimated construction costs are shown in Table 7.3.3.

(2) Operating Costs

Operating costs for the main sewer interceptor are estimated for inspection and minor cleaning works of the interceptor. Table 7.3.4 shows necessary staff number and their wages. The necessary staff number includes those for the operation of the water intake facilities.

TABLE 7.3.3 ESTIMATES OF CONSTRUCTION COST FOR MAIN SEWER INTERCEPTOR

Work items		Unit	Quantity	Unit Price(US$)	Amount (US$)
PC*-pipe installation					
under maintenance road	1000 mm	m	80	454	36,320
Arched masonry installation					
under maintenance road	1300 mm	m	50	365	18,250
under pedestrian	1300 mm	m	710	250	177,500
under pedestrian	1500 mm	m	1,120	277	310,240
under A class road	1500 mm	m	2,070	473	979,110
under B class road	1500 mm	m	1,260	425	535,500
under unpaved road	1500 mm	m	650	402	261,300
under river bed	1500 mm	m	3,760	535	2,011,600
Tunnel	1500 mm	m	300	1,712	513,600
Road construction					
maintenance (weir)		m	130	19	2,470
maintenance (river bed)		m	3,000	12	36,000
Groin works		set	10	7,260	72,600
Total Construction Cost					4,954,490

*Prestressed concrete

TABLE 7.3.4 ESTIMATES OF OPERATING COSTS FOR MAIN SEWER INTERCEPTOR

Staff	Nos.	Salary(US$/Year)
Engineers	1	4,950
Laborers	5	9,900
Night watch	1	1,650
Drivers	2	3,960
Total		20,460

7.4 WASTEWATER TREATMENT PLANT

7.4.1 General

Design flows and the characteristics of the wastewater to be treated are described in Chapters 4 and 5. The overall wastewater treatment plant is described in Appendix D. For the Priority Project, it is proposed to construct only a portion of the proposed lagoons and sedimentation basins at Site #1 (See Figure 7.4.1). For this first phase, the lagoons would be of the partially-mixed aerated type and would provide only primary treatment. As described in Section 5.4.1, the initial flow to the lagoon system is estimated at 140,000 m^3/day.

Two sites, Site #1 and #2 will be required for the entire project in the Basic Plan. Although only Site #1 is required for the Priority Project, it is recommended that Site #2 also be acquired in the first stage to prevent potential land speculation and acquisition problems which could affect the implementation of Phase 2.

At Site # 1 there is a total of about 20 Ha available. Since about 2 Ha are needed for roads, parking, berms, etc. there is about 18 Ha usable for process facilities. For the first phase project, it is proposed to provide the following facilities:

2 Ha Preliminary (inlet) treatment works and buildings

16 Ha Lagoons : partially-mixed aerated with sedimentation basins

7.4.2 Preliminary Treatment and Buildings

The preliminary treatment works (bar screen, grit chambers, and Parshall Flume) are discussed in Section 3 of Appendix D and are shown in Figure 7.4.2. The building requirements include an operations building with laboratory, office and meeting rooms, and storage/maintenance facilities for the aeration equipment. Consideration should also be given to the construction of staff housing at or near the site (not included in Project).

7.4.3 Aerated Lagoons

(1) General

It is proposed that the lagoon system for the Priority Project be composed of 2 parallel sets of cells, each set consisting of six 1 hectare cells plus one 2 hectare cell; see Figure 7.4.1.

Each aerated lagoon cell would have a maximum depth of 6 meters; refer to Figure 7.4.3. The last cells in each set would serve as sedimentation basins for solids removal and sludge retention/digestion. The first six cells in each set (total of 12 cells) would be partially aerated in the first phase. In the second phase, the partially aerated lagoons and the sedimentation basins would be converted to completely-mixed aerated lagoons and new sedimentation basins would be added at Site # 2 (see Figure D-4).

A profile of the first phase lagoon system is shown in Figure 7.4.4. Inlet facilities are depicted in Figures 7.4.5 and 7.4.6. The river bed at Site #1 will require fill to raise the plant site above flood levels; refer to Figure 7.4.4.