Part III

Environmental Sanitation Master Plan

Chapter 6

Planning Frameworks

6 Planning Frameworks

6.1 Social Framework

6.1.1 Future Developments

"*Programa Estatal de Desarrollo Urbano del Estado de Quintana Roo* (PEDU)" has been officially published in "*Periódico Oficial del Gobierno del Estado de Quintana Roo*" on 22 April 2002. This program develops scenario where overdevelopment in the north of the state is to be limited by POETs (*Programa de Ordenamiento Ecológico*) covering the region, and the south is to grow with balance between development and environment conservation, such as low impact tourism, according to POETs covering the area. The program estimates how communities are to develop in the future. In this Study, the program is considered as a kind of a superior plan.

6.1.2 Future Population

a. Residential Population

Population forecast is based on the estimate of PEDU except Playa del Carmen where the actual population exceeds the estimate.

Table 6-1: Population Forecast

Municipality	2003	2005	2010	2015
OTHON P BLANCO	228,683	269,647	358,299	415,189
FELIPE CARRILLO PUERTO	63,616	66,149	70,661	73,901
SOLIDARIDAD	142,666	204,049	311,429	403,704
Total	434,965	539,845	740,389	892,794

b. Number of Tourists

b.1 Number of Tourists per Year

Number of tourists is estimated in Costa Maya, Playa del Carmen, Aventuras - Akumal and Tulum where number of tourists at present and in the future exceeds much more than the permanent population. Table 6-2 presents a summary of the estimation of tourist numbers.

Table 6-2: Number of Tourists (Forecast)

Year	2003	2005	2010	2015
Costa Maya	80,468	217,000	221,000	225,000
Playa del Carmen	916,396	1,061,244	1,389,659	1,669,924
Aventuras – Akumal	637,791	732,149	873,206	960,403
Tulum	122,838	146,078	215,273	300,318
Total	1,757,493	2,156,471	2,699,138	3,155,645

b.2 Number of Tourist-day

The estimation above does not consider how many days each tourist stays in the regions. According to a statistical material[1], average length of stay per person in Riviera Maya is 6.59 days. With this number, number of tourist-day per year and day are estimated as shown in Table 6-3 and Table 6-4.

Table 6-3: Number of Tourist-day per Year

Year	Costa Maya	Playa del Carmen	Aventuras – Akumal	Tulum	Total
2003	530,283	6,039,050	4,203,046	809,502	11,581,881
2004	870,830	6,522,670	4,545,257	883,989	12,822,746
2005	1,430,030	6,993,598	4,824,864	962,654	14,211,146
2006	1,435,302	7,451,834	5,061,268	1,045,497	14,993,901
2007	1,440,574	7,897,377	5,266,051	1,132,518	15,736,520
2008	1,445,846	8,330,228	5,446,682	1,223,717	16,446,473
2009	1,451,118	8,750,387	5,608,262	1,319,094	17,128,861
2010	1,456,390	9,157,853	5,754,429	1,418,649	17,787,321
2011	1,461,662	9,552,627	5,887,869	1,522,382	18,424,540
2012	1,466,934	9,934,708	6,010,622	1,630,294	19,042,558
2013	1,472,206	10,304,098	6,124,273	1,742,383	19,642,960
2014	1,477,478	10,660,795	6,230,080	1,858,650	20,227,003
2015	1,482,750	11,004,799	6,329,056	1,979,096	20,795,701

Table 6-4: Number of Tourist-day per Day

Year	Costa Maya	Playa del Carmen	Aventuras – Akumal	Tulum	Total
2003	1,453	16,545	11,515	2,218	31,731
2004	2,386	17,870	12,453	2,422	35,131
2005	3,918	19,161	13,219	2,637	38,935
2006	3,932	20,416	13,866	2,864	41,078
2007	3,947	21,637	14,428	3,103	43,115
2008	3,961	22,823	14,922	3,353	45,059
2009	3,976	23,974	15,365	3,614	46,929
2010	3,990	25,090	15,766	3,887	48,733
2011	4,005	26,172	16,131	4,171	50,479
2012	4,019	27,218	16,467	4,467	52,171
2013	4,033	28,230	16,779	4,774	53,816
2014	4,048	29,208	17,069	5,092	55,417
2015	4,062	30,150	17,340	5,422	56,974

[1] ANUARIO ESTADISTICO Quintana Roo edición 2002 / INEGI

c. Number of Economic Activity Population

Supposing that number of Economic Activity Population (EAP) is to grow with economic growth rate, EAP is estimated as shown in Table 6-5 based on EAP in the census in 2000.

Table 6-5: Forecast of Economic Activity Population

Year	OTHON P BLANCO	FELIPE CARRILLO PUERTO	SOLIDARIDAD	Total
2000	63,808	16,626	27,162	107,596
2001	66,360	16,959	32,594	115,913
2002	69,014	17,298	38,461	124,773
2003	71,775	17,644	43,076	132,495
2004	74,646	18,085	49,537	142,268
2005	78,005	18,537	56,968	153,510
2006	81,515	19,000	62,665	163,180
2007	85,591	19,475	68,932	173,998
2008	90,299	19,865	75,825	185,989
2009	95,265	20,262	83,408	198,935
2010	100,505	20,667	91,749	212,921
2011	104,525	20,977	97,254	222,756
2012	108,706	21,292	103,089	233,087
2013	113,054	21,611	109,274	243,939
2014	117,576	21,935	115,830	255,341
2015	122,279	22,264	122,780	267,323

6.2 Economic Framework

6.2.1 Economic Growth

Economic growth in the three municipalities has been forecast taking into account economic data at the Federal and the State levels, population projection, etc. Table 6-6 summarizes the forecast.

Table 6-6: Forecast of Economic Growing Rate

Economic growing rate	OTHON P BLANCO	FELIPE CARRILLO PUERTO	SOLIDARIDAD	Quintana Roo total
2000	-	-	-	5.5%
2001	4.0%	2.0%	20.0%	5.0%
2002	4.0%	2.0%	18.0%	4.0%
2003	4.0%	2.0%	12.0%	3.0%
2004	4.0%	2.5%	15.0%	4.0%
2005	4.5%	2.5%	15.0%	4.0%
2006	4.5%	2.5%	10.0%	4.5%
2007	5.0%	2.5%	10.0%	5.0%
2008	5.5%	2.0%	10.0%	5.5%
2009	5.5%	2.0%	10.0%	5.5%
2010	5.5%	2.0%	10.0%	5.5%
2011	4.0%	1.5%	6.0%	5.0%
2012	4.0%	1.5%	6.0%	5.0%
2013	4.0%	1.5%	6.0%	5.0%
2014	4.0%	1.5%	6.0%	5.0%
2015	4.0%	1.5%	6.0%	5.0%

6.2.2 Industrial Structure

Rather than the existing partial data on the value of production by economic sector, the outlook on the industrial structure by Municipality was drawn from the data on population and the economically active population (EAP) of the Population Census 2000, in addition to the assumed labor participation rate (EAP/population) and the assumed economic growth rates. Table 6-7 summarizes forecast of EAP distribution.

Table 6-7: Assumed Industrial Structure as per EAP Distribution

Municipality	Sector	2001-2005	2006-2010	2011-2015
Othon P Blanco	Agriculture	20	15	10
	Industry	16	20	20
	Service	64	65	70
Felipe C Puerto	Agriculture	50	45	40
	Industry	12	15	15
	Service	38	40	45
Solidaridad	Agriculture	5	5	5
	Industry	20	20	20
	Service	75	75	75

6.3 Future Wastewater Amount and Quality

6.3.1 Wastewater Generation Rate

Wastewater generation rate is defined based on a manual of CNA[2]. The manual recommends for employing 75% of design water supply rate as wastewater generation rate for planning of sewerage facilities. Also, it recommends water supply rate depending on climate.

In planning the Master Plan, 230 liter/person/day is considered as waste supply rate as the Study Area belongs to "Hot climate." Then, 173 liter/person/day of wastewater generation rate is obtained as follows.

$$q = 230(liter / person / day) \times 75\% = 173(liter / person / day)$$

6.3.2 Wastewater Amount

Table 6-8 shows wastewater generation amount in the future obtained from the wastewater generation rate and future population forecast.

Table 6-8: Summary of Wastewater Generation Amount

Unit: m^3/day

MUNICIPALITY	2003	2005	2010	2015
OTHON P. BLANCO	39,813.7	47,326.7	62,676.2	72,529.8
FELIPE CARRILLO PUERTO	11,005.3	11,444.0	12,223.9	12,784.9
SOLIDARIDAD	29,920.0	41,358.4	61,614.6	78,991.5
Total	80,739.0	100,129.1	136,514.7	164,306.2

6.3.3 Future Wastewater Quality

The manual of CNA also defines pollutant load rates. With it and the wastewater generation rate, wastewater quality is assumed as one shown in below.

Table 6-9: Pollutant Load Rate

Item	Pollutant Load Rate (g/person/day)	Water Quality (mg/liter)
BOD	54	312
COD	110	636
SS	52	300
T-N	8	46
T-P	4.60	27

Source: Manual de Agua Potable, Alcantarillado y Saneamiento, Ver3.0, 2001 CNA II-3.-4.2

[2] Manual de Agua Potable, Alcantarillado y Saneamiento, Ver 3.0, 2001 CNA

6.4 Future Waste Amount and Composition

6.4.1 Waste Generation Rate

a. Households Waste

Detailed investigations on waste amount and composition were recently carried out in Chetumal, Felipe C Puerto City and Tulum in the "Executive Projects of Sanitary Landfills" financed by IDB. Household Waste Generation Rates are set as shown in the table below based on the results of the projects with taking into account data of JICA studies carried out in Latin American Countries.

Table 6-10: Household Waste Generation Rate

Municipality	Waste generation rate (g/person/day)
OTHON P. BLANCO	970
FELIPE CARRILLO PUERTO	802
SOLIDARIDAD	970

b. Non-household Waste

As the same as Household Waste Generation Rate, Non-household Waste Generation Rate was obtained from the Executive Projects. 601.0 g/day/EAP is employed in the planning as non-household waste generation rate.

c. Waste Generation Rate per Tourist

Tourists should be considered as waste generator in tourism areas. The same waste generation rate as one of household is employed for tourists.

6.4.2 Waste Composition

Based on the results of the Executive Projects, waste composition for the planning is set as shown in the table below.

Table 6-11: Waste Composition

Composition	Portion %
Paper	14.08
Kitchen waste	18.74
Textile	13.52
Grass & wood (garden waste)	17.19
Plastic	5.93
Rubber & leather	7.31
Metal	4.19
Glasses	8.67
Soil, stone, ceramic	7.06
Others	3.32
Total	100.00

6.4.3 Bulk Density

Bulk density of waste at generation point obtained from the Executive Projects. The average, 0.169, is employed in this planning.

6.4.4 Future Waste Amount

Table 6-12 shows estimation of waste generation amount in the future.

Table 6-12: Waste Generation Amount in the Future

Category	Year	Othon P Blanco	Felipe C Puerto	Solidaridad	Total
Household (ton/day)	2003	221.83	51.01	138.39	411.22
	2005	261.56	53.05	197.93	512.54
	2010	347.55	56.67	302.09	706.31
	2015	402.74	59.27	391.59	853.60
Non-household (ton/day)	2003	42.20	10.60	25.90	78.70
	2005	46.01	11.10	34.20	91.31
	2010	59.44	12.40	55.10	126.94
	2015	72.33	13.40	73.80	159.53
Tourist (ton/day)	2003	1.50	-	29.40	30.90
	2005	3.80	-	33.90	37.70
	2010	4.00	-	43.40	47.40
	2015	4.00	-	51.40	55.40
Total (ton/day)	2003	265.52	61.61	193.69	520.82
	2005	311.37	64.15	266.03	641.55
	2010	410.99	69.07	400.59	880.65
	2015	479.06	72.67	516.79	1,068.52

Chapter 7

Threats in the Future

7 Threats in the Future

On the basis of the understanding on the present situations of environmental sanitation, it is confirmed that if the situation is left as it is and the tourism development proceeds, the groundwater, which is only source of water supply and has links between other aquatic environments, will face threats of pollution and depletion. Then, it would be a significant factor to hamper sustainable development of the study area in the future as shown in Figure 7-1.

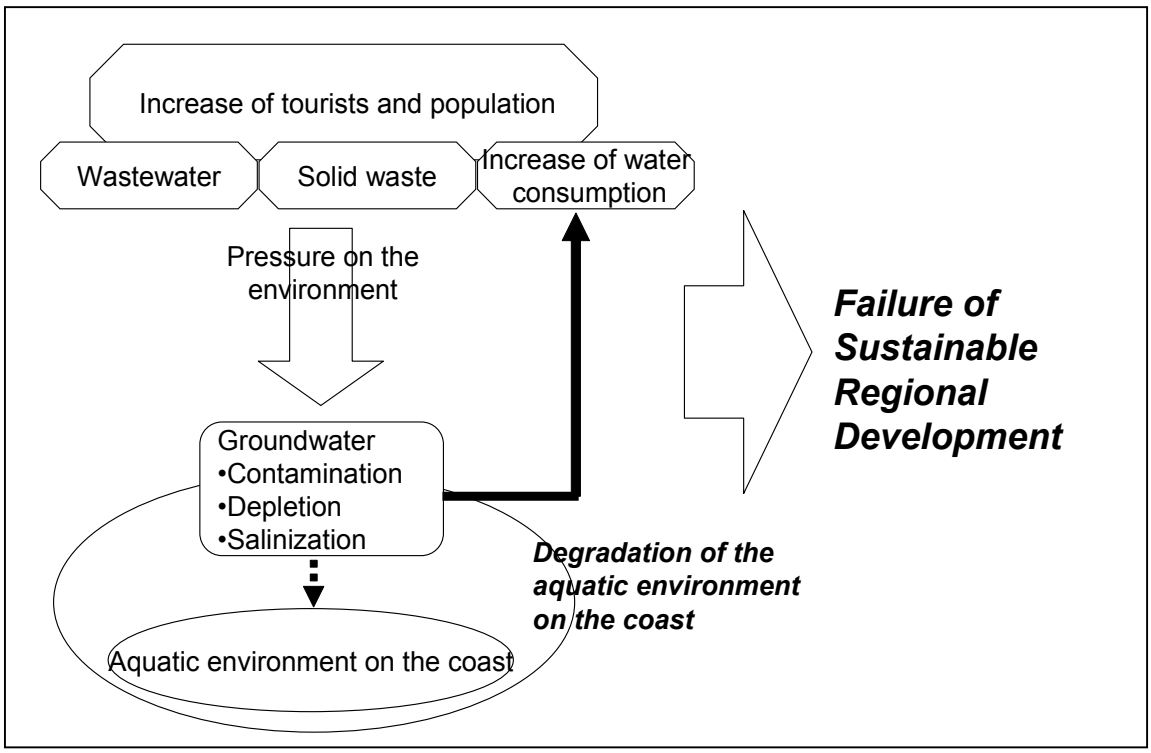


Figure 7-1: Groundwater and Sustainable Development

If no new measures are taken in the WWM and the SWM in the future, BOD discharge amount to the environment would increase from about 13 thousand ton in 2003 to about 26 thousand ton in 2015 as shown in Table 7-1. From the BOD amount and the water balance (See Table 7-2), BOD concentration is obtained as shown in Table 7-3. As the table shows, BOD concentration in the groundwater is estimated to increase up to 4.9 mg/liter in 2015. Only wastewater and solid waste are considered in the estimation. Therefore, it is presumed that BOD concentration in the groundwater would be higher than 4.9 mg/liter as there are other pollution sources such as agriculture.

Question is what sort of degree the BOD concentration of 4.9 mg/liter. As there is no environment standard of public water body in Mexico, the standard in Japan is taken up as a

reference. The BOD concentration of 4.9 mg/liter is categorized in Class B, being very close to Class C (See Table 7-4 and Table 7-5). Class C is defined as waste body that is required sophisticated purification for water supply.

Consequently, it is found that the groundwater would be so severely contaminated to deteriorate the coastal aquatic environment, if no measures are taken in the environmental sanitation management, or WWM and SWM.

Table 7-1: BOD Discharge Amount to the Environment

Unit: ton/year

Item	2003	2005	2010	2015
Wastewater				
OTHON P. BLANCO	4,397.1	5,227.5	6,922.2	8,010.5
FELIPE CARRILLO PUERTO	1,250.4	1,299.3	1,388.4	1,451.8
SOLIDARIDAD	1,446.7	1,999.7	2,979.2	3,819.3
Total	**7,094.2**	**8,526.5**	**11,289.8**	**13,281.6**
Solid Waste				
OTHON P. BLANCO	3,125.8	3,665.0	4,837.7	5,639.2
FELIPE CARRILLO PUERTO	725.5	754.7	813.0	855.5
SOLIDARIDAD	2,280.0	3,131.0	4,715.3	6,083.3
Total	**6,131.3**	**7,550.7**	**10,366.0**	**12,578.0**
Overall				
OTHON P. BLANCO	7,522.9	8,892.5	11,759.9	13,649.7
FELIPE CARRILLO PUERTO	1,975.9	2,054.0	2,201.4	2,307.3
SOLIDARIDAD	3,726.7	5,130.7	7,694.5	9,902.6
Total	**13,225.5**	**16,077.2**	**21,655.8**	**25,859.6**

Table 7-2: Water Balance in Quintana Roo State

Unit: million m^3／year

Item	Othón P. Blanco	Felipe C. Puerto	Solidaridad	Others	Total
Recharge and Flow in					
Recharge	1,801.3	1,611.0	346.0	1,265.9	5,024.1
Flow in	366.6	211.3	124.1	731.3	1,433.2
Total	**2,167.8**	**1,822.3**	**470.1**	**1,997.1**	**6,457.3**
Groundwater amount					
To sea	-927.8	-2,428.6	-862.6	-815.6	-5,035
Extraction	-124.0	-21.2	-30.0	-94.7	-270
Flow out to another area	-811.8	-31.0	0.0	-310.0	-1,153
Total	**-1,863.6**	**-2,480.8**	**-892.6**	**-1,220.3**	**-6,457.3**

Table 7-3: Estimated BOD Concentration of Groundwater

Unit: mg/litre

Wastewater	2003	2005	2010	2015
From wastewater filed				
OTHON P. BLANCO	2.4	2.8	3.7	4.3
FELIPE CARRILLO PUERTO	0.5	0.5	0.6	0.6
SOLIDARIDAD	1.6	2.2	3.3	4.3
Total	**1.4**	**1.6**	**2.2**	**2.5**
From solid waste filed				
OTHON P. BLANCO	1.7	2	2.6	3
FELIPE CARRILLO PUERTO	0.3	0.3	0.3	0.3
SOLIDARIDAD	2.6	3.5	5.3	6.8
Total	**1.2**	**1.4**	**2**	**2.4**
Overall				
OTHON P. BLANCO	4.0	4.8	6.3	7.3
FELIPE CARRILLO PUERTO	0.8	0.8	0.9	0.9
SOLIDARIDAD	4.2	5.7	8.6	11.1
Total	**2.5**	**3.1**	**4.1**	**4.9**

Table 7-4: Environmental Standard of Public Water Body (River) in Japan

Class	Water usage	pH	BOD mg/liter	SS mg/liter	DO mg/liter	Total coliform MPN/100ml
AA	• Water supply class 1 • Conservation natural environment • Usages list in A-E	6.5 to 8.5	1 or less	25 or less	7.5 or more	50 or less
A	• Water supply class 2 • Fisher class 1 • Usages list in B-E	6.5 to 8.5	2 or less	25 or less	7.5 or more	1,000 or less
B	• Water supply class 3 • Fisher class 2 • Usages list in C-E	6.5 to 8.5	3 or less	25 or less	5 or more	5,000 or less
C	• Fisher class 3 • Industrial water class 1 • Usages list in D-E	6.5 to 8.5	5 or less	50 or less	5 or more	-
D	• Industrial water class 2 • Conservation natural environment • Usages list in E	6.5 to 8.5	8 or less	100 or less	2 or more	-
E	• Industrial water class 3 • Conservation of the environment	6.0 to 8.5	10 or less	Floating matter such as garbage should be observed	2 or more	-

Source: Water Environment in Japan, Ministry of Environment in Japan

Table 7-5: Definitions of Water Usage to Environmental Standard of Public Water Body (River) in Japan

Item	Definitions
Conservation natural environment	Conservation of natural environment for natural sightseeing purposes (e.g. Natural park, world natural heritage, etc)
Water supply class 1	Water source for drinkable water production by low level water purification (e.g. sand filter, etc.)
Water supply class 2	Water source for drinkable water production by normal level water purification (e.g. chemical settling and sand filter, etc.)
Water supply class 3	Water source for drinkable water production by advanced level water purification (e.g. chemical settling and sand filter with activated carbon absorption, etc.)
Fisher class 1	Highly oligotrophic water body
Fisher class 2	Oligotrophic water body
Fisher class 2	Intermediate between eutrophic and oligotrophic water body
Industrial water class 1	Water source for industrial water production by normal level water purification (e.g. simple settling, etc.)
Industrial water class 2	Water source for industrial water production by advanced level water purification (e.g. chemical settling, etc.)
Industrial water class 3	Water source for industrial water production by special level water purification
Conservation of the environment	No sickening for living environment

Chapter 8

Consideration of Alternatives

8 Consideration of Alternatives

8.1 Consideration of Principal Objective

Principal objective of the Study is to formulate a Master Plan (M/P) of wastewater management (WWM) and solid waste management (SWM) aiming at preserving the coastal aquatic environment in the Study Area. Namely,

Principal objective of the M/P is to preserve the aquatic environment.

Meanwhile, it has been so far understood that pollution load originated from the sectors of WWM and SWM on the groundwater is the most significant environmental impact due to the geological characteristic, then preservation of the groundwater from the pollution load should be focused as the groundwater is closely related to the coastal environment such as cenotes, caves and coral reefs in the Study Area.

Although there are various indicators to grasp pollution load originated from wastewater and solid waste, it is recommendable to focus on BOD in the planning of the Master Plan, as wastewater and solid waste in the Study Area are originated from domestic activities and BOD is the most common indicator to evaluate pollution load cased by domestic activities. BOD amount has close relation with other pollutant such as coliform, nitrogen and phosphorus. Therefore, control of BOD amount leads to controlling other pollutants.

a. BOD Concentration in the Groundwater

As mentioned before, the environmental standard in Japan for the public water body defines Class AA for natural environment conservation, of which water quality is BOD concentration of 1 mg/liter and below. It is proposed to refer this standard to preserve the coastal aquatic environment in the Study Area, as such standard does not exist in Mexico. The proposal is as follows.

To set upper limit of BOD discharge amount from the WWM sector and the SWM sector in order to control BOD concentration in the groundwater 1mg/liter and below.

Amount of the groundwater in the Study Area is estimated as 5,237 million m^3/year as shown in Table 8-1. In order to control BOD concentration 1 mg/liter and below, BOD inflow to the groundwater should be 5,237 ton/year and below.

$$BOD\_amount = 5{,}237{,}000{,}000(m^3 / year) \times \left(\frac{1(mg / litre)}{1{,}000 \times 1{,}000} \right) = 5{,}237(ton / year)$$

Table 8-1: Estimated Groundwater Amount in the Study Area

Unit: million m^3／year

Item	Othón P. Blanco	Felipe C. Puerto	Solidaridad	Total
To sea	927.8	2,428.6	862.6	4219.0
Extraction	124.0	21.2	30.0	175.2
Flow out to anther area	811.8	31.0	0.0	842.8
Total	**1,863.6**	**2,480.8**	**892.6**	**5,237.0**

b. BOD Generation Amount

It is estimated that BOD generation amount in 2015 would be 18,719 ton/year in the WWM sector and 12,578 ton/year, 31,297 ton/year in total. This is more than double that in 2003 as shown in Table 8-2.

According to Table 8-3, 60% of the BOD amount would be from the WWM sector and 40% from the SWM sector. In respective municipalities, BOD generation amount in Felipe C Puerto would be much less than those in other municipalities. Only 8% of the BOD amount would be generated in the municipality. Meanwhile, Othon P Blanco and Solidaridad would generate significant amount of BOD. Both municipalities generate more than 40% each. Furthermore, the BOD amount generated in Solidaridad would increase more rapidly than that in Othon P Blanco.

Table 8-2: Forecast of BOD Generation Amount

Unit: ton/year

Item	2003	2005	2010	2015
Wastewater				
OTHON P. BLANCO	4,535.9	5,392.5	7,140.7	8,263.4
FELIPE CARRILLO PUERTO	1,254.5	1,303.6	1,393.0	1,456.6
SOLIDARIDAD	3,408.7	4,711.8	7,019.9	8,999.4
Total	9,199.1	11,407.9	15,553.6	18,719.4
Solid Waste				
OTHON P. BLANCO	3,125.8	3,665.0	4,837.7	5,639.2
FELIPE CARRILLO PUERTO	725.5	754.7	813.0	855.5
SOLIDARIDAD	2,280.0	3,131.0	4,715.3	6,083.3
Total	6,131.3	7,550.7	10,366.0	12,578.0
Overall				
OTHON P. BLANCO	7,661.7	9,057.5	11,978.4	13,902.6
FELIPE CARRILLO PUERTO	1,980.0	2,058.3	2,206.0	2,312.1
SOLIDARIDAD	5,688.7	7,842.8	11,735.2	15,082.7
Total	15,330.4	18,958.6	25,919.6	31,297.4

Table 8-3: Share of BOD Generation Amount

Item	2003	2005	2010	2015
Wastewater				
OTHON P. BLANCO	29.6%	28.4%	27.5%	26.4%
FELIPE CARRILLO PUERTO	8.2%	6.9%	5.4%	4.7%
SOLIDARIDAD	22.2%	24.9%	27.1%	28.8%
Total	60.0%	60.2%	60.0%	59.8%
Solid waste				
OTHON P. BLANCO	20.4%	19.3%	18.7%	18.0%
FELIPE CARRILLO PUERTO	4.7%	4.0%	3.1%	2.7%
SOLIDARIDAD	14.9%	16.5%	18.2%	19.4%
Total	40.0%	39.8%	40.0%	40.2%
TOTAL	100.0%	100.0%	100.0%	100.0%

c. Upper Limit of BOD Discharge Amount

BOD generation amount in 2015 is estimated as 31,297 ton/year, meanwhile discharge limit is 5,237 ton/year in order to control BOD concentration in the groundwater 1 mg/liter and below. Therefore, 26,060 ton/year of BOD amount should be removed.

Consequently, it is proposed to set upper limits of BOD discharge amount below 3,132.3 ton/year in the WWM sector and 2,104.7 ton/year in the SWM sector.

Table 8-4: Required BOD Removal Amount in 2015

Item	Required BOD removal amount (ton/year)
Wastewater	15,587.1
Solid waste	10,473.3
Total	26,060.4

Table 8-5: Upper Limit (Target Number) of BOD Discharge Amount in 2015

Item	Upper limit of BOD Discharge Amount
Wastewater	3,132.3
Solid waste	2,104.7
Total	5,237.0

8.2 Wastewater Management

8.2.1 Consideration of Objectives and Target Setting

8.2.1.1 Principal Objectives and Target Value

The principal objective of the Wastewater Management (WWM) Master Plan is;

To preserve the groundwater and the coastal aquatic environment in the study area

Target value is;

BOD discharge amount originated from wastewater is to be less than 3,100 ton/year by 2015.

8.2.1.2 Target Values in Various Size of Communities

This section considers how to cope with various sizes of communities dispersed over the Study Area, in order to achieve the target value of the principal objective.

a. BOD Generation Amount by Community Size

In 2015, BOD generation in communities having a population less than 100 is only 0.4%. Communities having a population between 100 and 2,499 occupy 12.8%. Communities having a population of 2,500 and over occupy 86.6% as shown in Table 8-6.

Table 8-6: BOD Generation Amount by Community Size (2015)

Population size	Total population	Wastewater amount (m^3/day)	Pollution load (BOD ton/year)	Contribution of pollution load
Less than 100	3,846	664.8	75.5	0.4%
100 to 499	19,431	3,361.7	383.7	2.0%
500 to 999	39,916	6,905.6	786.5	4.2%
1,000 to 1,499	28,631	4,952.8	564.0	3.0%
1,500 to 2,499	33,914	5,867.1	668.4	3.6%
2,500 to 4,999	37,229	6,440.6	733.8	3.9%
5,000 to 9,999	34,510	5,970.1	680.1	3.6%
10,000 to 19,999	37,428	6,475.0	737.7	3.9%
20,000 to 49,999	114,109	19,740.8	2,249.1	12.0%
50,000 to 99,999	76,088	13,163.3	1,499.7	8.0%
100,000 and over	524,649	90,764.4	10,340.9	55.2%
Total	949,751	164,306.2	18,719.4	100.0%

b. Wastewater Treatment Level by Community Size

Population density is generally low in small communities and pollution load caused by their domestic activities could be assimilated by the surroundings. Meanwhile, large communities are highly populated and economy is active. Then, pollution load of the large communities are much more significant compared to that in rural communities.

It is not strategic approach to take a certain measure to the various sizes of communities. Therefore, it is recommendable to set targets depending on community size as shown in Table 8-7. For example, simple treatment is employed for small communities and advanced treatment is adopted for large communities. If such targets are set, BOD discharge amount originated from the WWM sector to the environment is 3,026 ton/year as shown in Table 8-8.

Table 8-7: Required Treated Water Quality

Population size of community	Required treated water quality(BOD mg/liter)	Treatment level
Less than 100	312.1	Level 0(No sewer system)
100 to 1,499	150	Level 1
1,500 to 9,999	75	Level 2
10,000 to 49,999	50	Level 3
More than 50,000	30	Level 4

Table 8-8: Results of the Required Treated Water Quality Examination in 2015

Population size	Total population	Wastewater amount (m^3/day)	Pollution load (BOD ton/year)	Share of pollution load	Required treated water quality (BOD mg/liter)	Discharge pollution load (BOD ton/year)	Reduce amount (BOD ton/year)
Less than 100	3,846	664.8	75.5	0.4%	312.1	75.5	0.0
100 to 499	19,431	3,361.7	383.7	2.0%	150	184.1	199.6
500 to 999	39,916	6,905.6	786.5	4.2%	150	378.1	408.4
1,000 to 1,499	28,631	4,952.8	564.0	3.0%	150	271.2	292.8
1,500 to 2,499	33,914	5,867.1	668.4	3.6%	75	160.6	507.8
2,500 to 4,999	37,229	6,440.6	733.8	3.9%	75	176.3	557.5
5,000 to 9,999	34,510	5,970.1	680.1	3.6%	75	163.4	516.7
10,000 to 19,999	37,428	6,475.0	737.7	3.9%	50	118.2	619.5
20,000 to 49,999	114,109	19,740.8	2,249.1	12.0%	50	360.3	1,888.8
50,000 to 99,999	76,088	13,163.3	1,499.7	8.0%	30	144.1	1,355.6
100,000 and over	524,649	90,764.4	10,340.9	55.2%	30	993.9	9,347.0
Total	949,751	164,306.2	18,719.4	100.0%	50.5	**3,025.7**	15,693.7

8.2.2 Consideration of Treatment Methods

There exist various treatment methods of domestic wastewater that mainly consists of organic matters such as BOD. Those treatment methods are basically classified into two categories; anaerobic treatment and aerobic treatment.

The anaerobic treatment utilizes digestion process of anaerobic bacteria for decomposition and removal of organic matters.

The aerobic treatment oxidizes, decomposes and removes organic matters with supply of oxygen by, for example, diffused-air aeration. Compared with the anaerobic treatment, the aerobic treatment achieves high quality of treated water. However, it requires power to supply oxygen. It brings higher costs of facilities, construction and operation. The following figure explains those differences between the aerobic treatment and the anaerobic treatment in BOD removal.

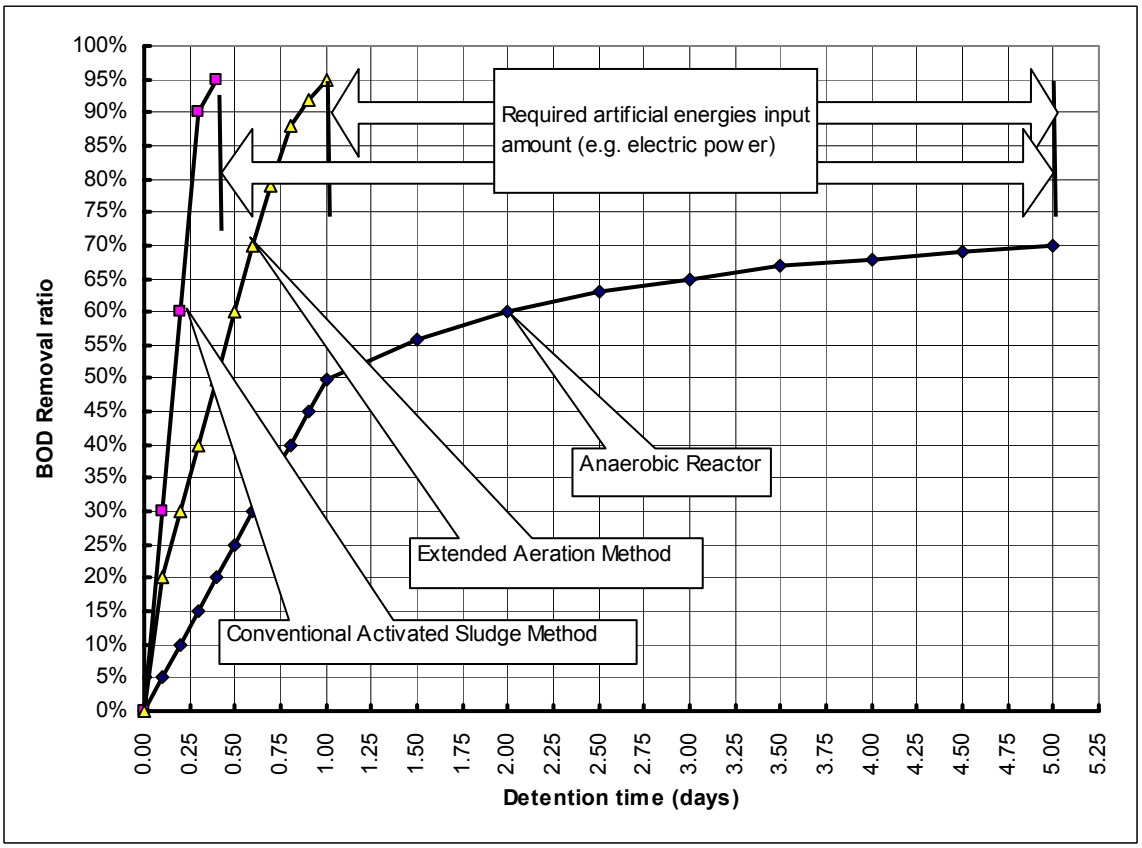


Figure 8-1: Concept of BOD Removal and Treatment Method

Required treated water quality is set depending on community size as shown in the following table.

Table 8-9: Target Treatment Level by Communities Size

Treatment level	Population size of community	Required target treated water quality and BOD removal Ratio	
		BOD (mg/liter)	BOD remove ratio
Level 1	100 to 1,499	150	52 %
Level 2	1,500 to 9,999	75	76 %
Level 3	10,000 to 49,999	50	84 %
Level 4	More than 50,000	30	90 %

8.2.3 Selection of Treatment Methods

Various treatment methods were considered in order to find appropriate methods for the various sizes of communities. Consequently, treatment methods shown in the table below have been recommended.

Table 8-10: Proposed Treatment Method

Treatment level	Population size of community	Treatment method
Level 1	100 to 1,499	An-aerobic reactor + disinfection
Level 2	1,500 to 9,999	An-aerobic reactor + aerobic filter + disinfection
Level 3	10,000 to 49,999	Oxidation ditch + disinfection
Level 4	More than 50,000	Activated sludge + disinfection

8.2.4 Consideration of Financial Aspect

The income from wastewater treatment comprised only around 3% of total CAPA income between 2000 and 2002, while the operation cost alone amounted to around 7%. More specifically, expenditures on wastewater treatment varied from 2.2 times to 3.2 times the income from wastewater treatment service.

The wastewater generation was estimated at 75% of water production, about twice as much as the billed water volume. Treated wastewater was estimated at around 20% of water production and 25% of generated wastewater. Although the tariff for wastewater treatment was set at 20% of water rates, the collected monetary amount was relatively small due possibly to the low degree of household connection to the sewer system.

Under these circumstances, the wastewater treatment activity was financially negative in the past three years, as shown in the following Table.

Table 8-11: CAPA Wastewater Income & Expenditures (Mill. Pesos)

	2000	2001	2002
Wastewater Income	3.89	4.69	6.74
Wastewater Expenditures	10.86	14.96	14.91
Operation Cost	8.89	12.37	12.57
Maintenance Cost: Electromec.	1.32	1.02	1.33
Maint. Cost: Wastewater Pipe	0.23	0.74	0.33
Quality Control of Wastewater	0.42	0.83	0.68
Income - Expenditures	-6.97	-10.27	-8.17

Source: CAPA

Then, the issue is the financial deficit of the wastewater treatment service, or how to reduce the gap between income and expenditures specific to the service.

8.3 Solid Waste Management

8.3.1 Consideration of Objectives and Target Setting

8.3.1.1 Principal Objective and Targeted Value

The principal objective of the Solid Waste Management (SWM) Master Plan is:

To preserve the groundwater and the coastal aquatic environment in the study area

Targeted value is:

BOD discharge amount originated from solid waste is to be less than 2,100 ton/year by 2015.

8.3.1.2 Particular Objectives and Targeted Values

The master plan being formulated should aim at achieving the targeted value of the principal objective, in addition, should accomplish the following objectives inherent to solid waste management.

- ***Provision of sanitary living environment:*** by removing waste from houses and communities
- ***Mitigation of environmental impact cased by waste:*** by properly disposing of collected waste
- ***Resource conservation:*** by contributing to establishment of a recycling-oriented society through waste minimization

The particular objectives above should have targeted values with a time frame as follows: i) collection rate is a representative indicator for provision of sanitary living environment; ii) final disposal level can show degree of mitigation of environmental impact caused by waste; and iii) waste minimization rate is one of indicators representing resource conservation. Targeted values in regard to the three points are to be set through discussion below.

a. Issues in Setting Collection Rate

a.1 Demand for Solid Waste Management

Demand for solid waste management vary, e.g., small rural communities may not require waste collection service, meanwhile large communities such as Chetumal and Playa del Carmen require high level of SWM. Priority of SWM should be basically given in order as follows; i) large population and high population density, ii) small population but high density

or large population but low density, iii) small population and low density. The figure below schematizes this concept.

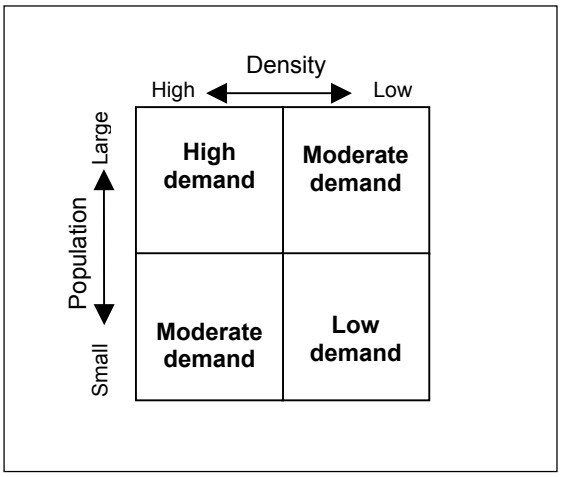


Figure 8-2: Relation among Population Size, Density and Demand for SWM

a.2 Various Size of Communities dispersed over the Study Area

The study area has a population of about 500,000 in 2003 over the huge area of 36,000 km^2. The population is distributed to 288 communities. Sizes of communities vary from dozens to over 100,000.

Numbers of urban communities are 15 in 2003 and 24 in 2015, which are less than 10% of the total number of communities. However, populations of the communities occupy 75% in 2003 and 85% in 2015 of the total population as shown in Table 8-12. Waste amounts generated from those urban communities occupy more than 80% in 2003 and almost 90% in 2015 of the total amount as shown in Table 8-13.

As the figures tell, to focus on urban communities to cope with SWM problems will be effective and efficient. Urban communities being having a population 2500 and over in 2015 is shown in Table 8-14. PEDU groups communities with taking into account vicinity, economic relation, etc., and calls those groups as urban systems. In this planning, the 24 target communities are gathered up to 10 groups based on the urban systems of PEDU. Table 8-15 shows the grouping.

Table 8-12: Population in Urban and Rural Areas

Year	2003		2015	
Community Size	Nos.	%	Nos.	%
Rural (2,499 and below)	110,571	25.4	130,408	14.6
Urban (2,500 and over)	324,394	74.6	762,386	85.4
Total	434,965	100.0	892,794	100.0

Table 8-13: Waste Generation Amount in Urban and Rural Areas

Year	2003		2015	
Community Size	ton/day	%	ton/day	%
Rural (2,499 and below)	94.7	18.2	122.7	11.5
Urban (2,500 and over)	426.1	81.8	945.9	88.5
Total	520.8	100.0	1,068.6	100.0

Table 8-14: Target Communities of Master Plan

	Community	Population in 2015 (nos.)
I. Othon P Blanco		
1	Alvaro Obregon	4,156
2	Bacalar	21,618
3	Calderitas	6,359
4	Chetumal	163,275
5	Ingenio Alvaro Obregon	4,585
6	Limones	18,752
7	Mahahual	73,335
8	Maya Balam	3,048
9	Nicolas Bravo	4,854
10	Punta Pulticub	8,440
11	Sergio Butron Casas	3,733
12	Xahuachol	18,000
13	Xcalak	8,440
14	Xul-ha	2,854
	Sub-total	341,449
II. Felipe C Puerto		
1	Chunhuhub	5,410
2	Felipe Carrillo Puerto	22,069
3	Senor	2,940
4	Tepich	2,627
5	Tihosuco	5,227
	Sub-total	38,273
III. Solidaridad		
1	Ciudad Chemuyil	21,335
2	Coba	3,000
3	Nuevo Akumal	100,000
4	Playa del Carmen	214,664
5	Tulum	43,665
	Sub-total	382,664
	Total	762,386

Table 8-15: Grouping of Communities

Urban group	Community	Population (nos.)
I. Othon P Blanco		
1	CALDERITAS, CHETUMAL, XUL-HA	172,488
2	ALVARO OBREGON, INGENIO ALVARO OBREGON, SERGIO BUTRON CASAS	12,474
3	NICOLAS BRAVO	4,854
4	BACALAR, LIMONES, MAYA BALAM	43,418
5	MAHAHUAL, PUNTA PULTICUB, Xahuachol, XCALAK	108,215
II. Felipe C Puerto		
6	FELIPE CARRILLO PUERTO, SENOR	25,009
7	CHUNHUHUB	5,410
8	TEPICH, TIHOSUCO	7,854
III. Solidaridad		
9	CIUDAD CHEMUYIL, NUEVO AKUMAL, PLAYA DEL CARMEN, TULUM	379,664
10	COBA	3,000
Total		762,386

a.3 Target Values of Collection Rate

Taking into account demand for SWM, such as waste collection and disposal, and efficiency and effectiveness of those implementations, it should prioritize to realize sound solid waste management in cities having large population, i.e. urban communities. However, even in urban communities, fringe areas often do not require regular waste collection service, especially in small urban communities. This could be taken into account when setting a target of collection coverage rate. Two options have been set in regard to setting a target of collection coverage as follows.

1. 100% of collection coverage over the all urban communities
2. 80 to 100% of collection coverage depending on population size of a community

Table 8-16: Consideration of Collection Rate (Case 1)

Population (nos.)	Collection Rate
1 – 2,499	0%
2,500 - 7,999	80%
8,000 - 34,999	90%
34,999 - 99,999	95%
100,000 -	100%

Table 8-17: Consideration of Collection Rate (Case 2)

Population (nos.)	Collection Rate
1 – 2,499	0%
2,500 -	100%

b. Issues to be considered in Setting Final Disposal Level

b.1 Phased Development of Waste Disposal

BOD amount originated from solid waste can be reduced remarkably by application of appropriate disposal manners. Sanitary landfilling is the most effective manner to reduce BOD amount, however, its construction and operation require a large amount of money and high level of technology. In the study area, there is no this sophisticated type of sanitary landfill yet. Phased development of waste disposal towards the sanitary landfill shown in Table 8-18 is recommendable.

Table 8-18: Phased Development of Waste Disposal

Disposal level	Contents
0:Open dump	• No control • Waste is scattered all over a dumping site. • No rainwater drainage system • Large amount of leachate is generated • No biogas control (fire, slow decomposition of waste) • Poor quality of leachate due to anaerobic condition
1:Controlled dump	• Inspection on incoming waste: to measure disposal amount, to control hazardous waste, etc. • Approach road, on-site road: to secure access to a dumping area • Landfill equipment: to accumulate waste
2:Enclosed dump	• Fence: to prohibit for unauthorized persons to enter the site • Dike: to avoid waste to be scattered, to prevent water from coming in • Buffer: to keep enough space to adjacent property • Drainage: surrounding and on-site drains
3:Landfill with gas control	• Soil cover: to prohibit vector proliferation, to prevent fire and mal odor, to minimize rainwater infiltration, to improve aesthetics • Gas removal facility: to prevent fire and explosion, to encourage waste decomposition • Weighbridge: important for SWM
4:Landfill with leachate control	• Bottom liner: to prevent leachate to infiltrate into ground (groundwater contamination) • Leachate collection facility: to collect and discharge leachate to the outside • Leachate treatment facility: to treat leachate to a certain quality that does not give serious environment impact

b.2 Comparison of BOD Reduction

Reduction of BOD amount is considered at each level of waste disposal with supposing height of filling, bulk density after compaction, etc. Supposing that BOD amount from open dump as 100%, controlled dump would reduce it by 50%, enclosed dump by 20%, landfill with gas control by 8.33%, and landfill with leachate control by 0.29%.

b.3 Application of Phased Development of Disposal to Urban Groups

Two cases how to apply the phased development of waste disposal are set as shown in Table 8-19. L1 applies controlled dump, enclosed dump and landfill gas control and sanitary landfill with leachate control according to population size. L2 adopts sanitary landfill with leachate control to all urban groups with disregard to population size.

Table 8-19: Application of Phased Development of Disposal

Population	L1	L2
1 - 2,499	0	0
2,500 - 7,999	1	4
8,000 - 34,999	2	4
34,999 - 99,999	3	4
100,000 -	4	4

0: open dump
1: controlled dump
2: enclosed dump
3: landfill with gas control
4: landfill with leachate control

Urban G	Communities	Population (nos.)	L1	L2
1	CALDERITAS, CHETUMAL, XUL-HA	172,488	4	4
2	ALVARO OBREGON, INGENIO ALVARO OBREGON, SERGIO BUTRON CASAS	12,474	2	4
3	NICOLAS BRAVO	4,854	1	4
4	BACALAR, LIMONES, MAYA BALAM	43,418	3	4
5	MAHAHUAL, PUNTA PULTICUB, XAHUACHOL, XCALAK	108,215	4	4
6	FELIPE CARRILLO PUERTO, SENOR	25,009	2	4
7	CHUNHUHUB	5,410	1	4
8	TEPICH, TIHOSUCO	7,854	1	4
9	CIUDAD CHEMUYIL, NUEVO Akumal, PLAYA DEL CARMEN, TULUM	379,664	4	4
10	COBA	3,000	1	4
91	Rural Communities	130,408	0	0

c. Issues in Setting Waste Minimization

Waste minimization is currently the central problem of Solid Waste Management. Developed countries have taken the lead in waste minimization so far. However, other countries are also expected to tackle it, as the waste minimization is one of effective measures to preserve natural resources, to prevent the global warming, to reduce hazardous substances and to lower SWM cost.

c.1 Concept of Waste Minimization

Waste minimization has a broad sense, which includes Generation Control, Discharge Control and Resource Recovery as shown in the figure below.

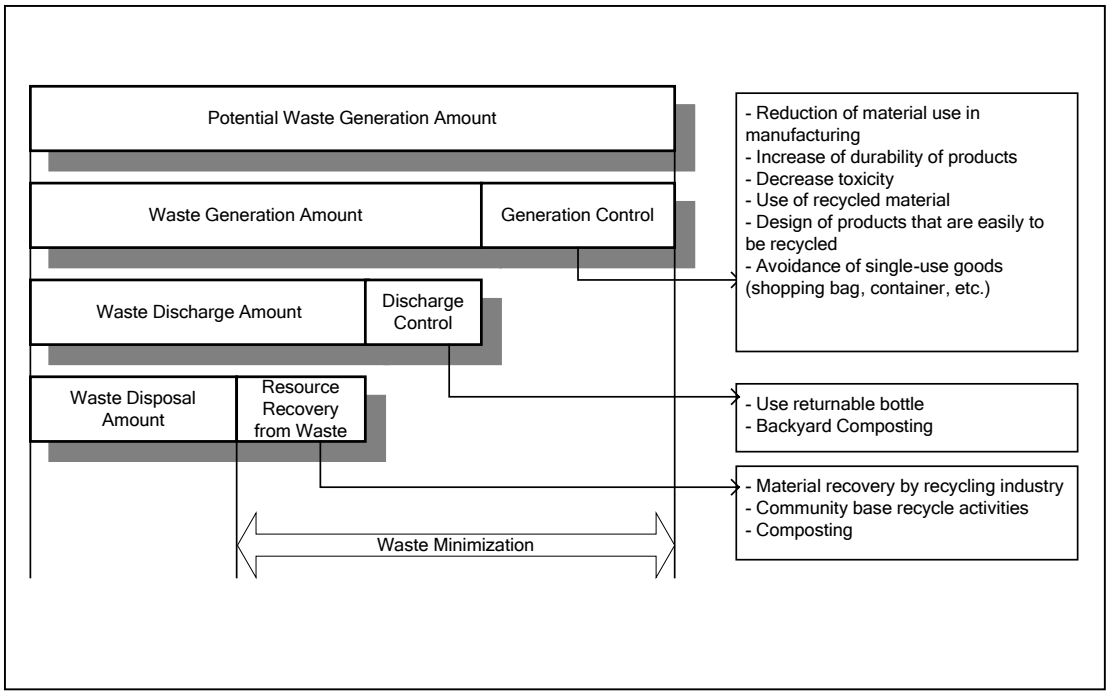


Figure 8-3: Concept of Waste Minimization

It is common knowledge around the world that the priority order of SWM policy is 1) to "Reduce," 2) to "Reuse" and 3) "Recycle."

"Generation Control" is the same as reduce. It should be given the first priority. "Discharge Control" practices reuse and/or recycle at waste generation sources. As both measures aims to reduce waste discharged from the generation source, they are called as "Source Reduction."

"Resource Recovery" indicates activities which aim to recover resources from discharged waste. It is generally called as "Recycling." It is often divided into "Material Recovery" and "Energy Recovery."

In this context, "Generation Control" and "Discharge Control" mean as "Source Reduction," and "Resource Recovery" means as "Recycling" in this planning.

c.2 Towards to Waste Minimization in Mexico

"Ley General para la Prevencion y Gestion Integral de los Residuos" has been promulgated in October 2003. The law puts importance on the following four issues.

- Prevention of waste generation
- Valorization of waste
- Integral management of waste
- Sharing of responsibility

In addition, a SWM campaign "Mexico Limpio" has been carried out ahead of the promulgation of the law, and various measures have been taken at federal, state and municipal levels. Political environment for waste minimization are in place in Mexico.

c.3 Disposal Cost

A major reason why recycling is feasible in developed countries is high cost of waste disposal. That is, waste minimization reduces disposal cost as well as waste disposal amount, and it compensates cost of recycling.

Meanwhile, disposal cost is often not so expensive in developing countries as to compensate recycling cost. In this case, recycling makes bigger financial burden and ceases its operation.

c.4 Waste Composition

Waste composition in the Study Area has about 30% of compostable waste. Backyard composting would be an effective measure to reduce waste at generation source. As for recycling, the waste composition tells that about 30% of waste is recyclable.

c.5 Waste Minimization Rate

About 60% of waste is potentially recyclable. However, all of them are not to practically be recycled, because some of materials are contaminated and some of organic materials does not decompose quickly and not suit to composting. Degree of recycling could be encouraged by promotion and/or education. Taking into consideration the mentioned above, the following five options could be conceivable.

1) 0% of waste minimization: no measures for waste minimization

2) 2.5% of waste minimization: change of consumption behavior by environmental education

3) 15% of waste minimization: source reduction by backyard composting, recycling of papers and others, and change of consumption behavior by environmental education

4) 25% of waste minimization: 15% of source reduction by backyard composting, recycling of papers and others, and change of consumption behavior by environmental education; 10% of yard trimming composting (garden waste in households and pruning waste in public areas)

5) 40% of waste minimization: 15% of source reduction by backyard composting, recycling of papers and others, and change of consumption behavior by environmental education; 10% of yard trimming composting (garden waste in households and pruning waste in public areas); 15% of material recovery.

8.3.2 Setting of Alternative Scenarios

This section sets some technical alternative scenarios taking into consideration of characteristics of the Study Area. The minimum requirement is to achieve the principal objective, i.e., less than 2,100 ton/year of BOD discharge amount in 2015.

8.3.2.1 Alternative Scenarios

The following five scenarios are set. Contents of the scenarios explain situations to be achieved in 2015.

Scenario 1: Conventional System
- 0% of waste minimization: no measures for waste minimization
- 100% of waste collection rate in the urban area
- Sanitary landfills are adopted in all the urban area

Scenario 2: Conservative Recycling-oriented System
- 2.5% of waste minimization: change of consumption behavior by environmental education
- 80 - 100% of waste collection rate depending on population size of community
- Different disposal levels are adopted depending on population size of community

Scenario 3: Semi-progressive Recycling-oriented System
- 15% of waste minimization: source reduction by backyard composting, recycling of papers and others, and change of consumption behavior by environmental education
- 80 - 100% of waste collection rate depending on population size of community
- Different disposal levels are adopted depending on population size of community

Scenario 4: Progressive Recycling-oriented System
- 25% of waste minimization: 15% of source reduction by backyard composting, recycling of papers and others, and change of consumption behavior by environmental education; 10% of yard trimming composting (garden waste in households and pruning waste in public areas)
- 80 - 100% of waste collection rate depending on population size of community
- Different disposal levels are adopted depending on population size of community

Scenario 5: Radical Recycling-oriented System
- 40% of waste minimization: 15% of source reduction by backyard composting, recycling of papers and others, and change of consumption behavior by environmental education; 10% of yard trimming composting (garden waste in households and pruning waste in public areas); 15% of material recovery
- 80 - 100% of waste collection rate depending on population size of community
- Different disposal levels are adopted depending on population size of community

The table below summarizes the five scenarios.

Table 8-20: Alternative Scenarios

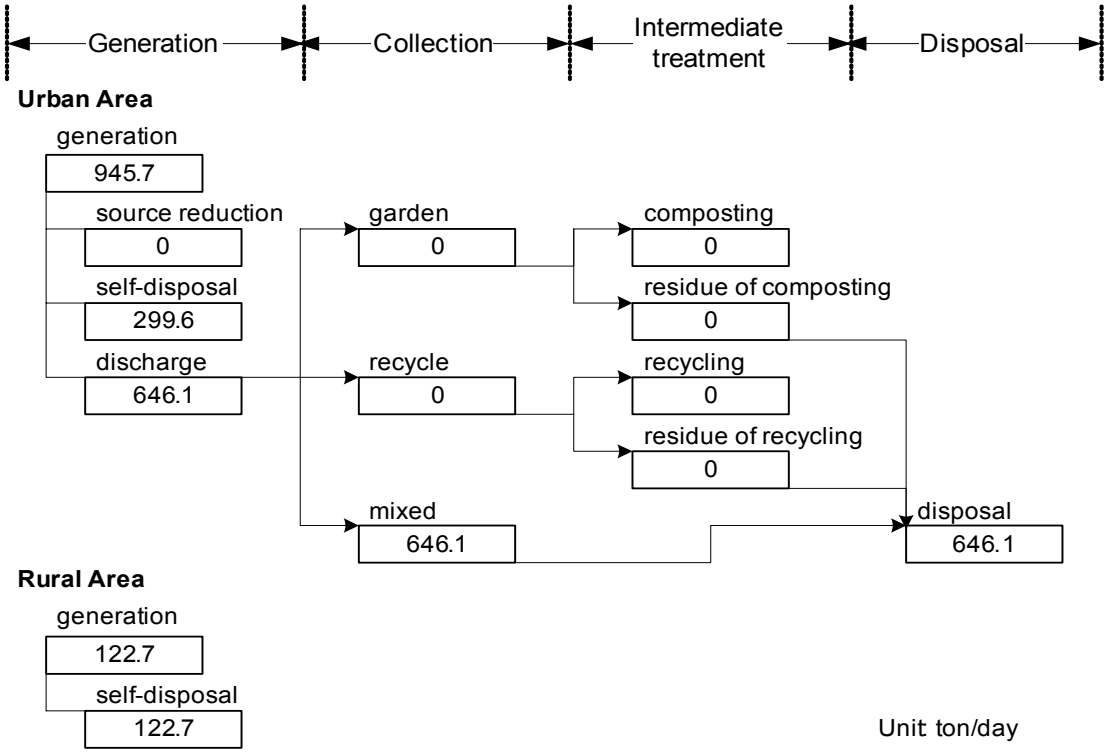
Scenario	Collection rate	Disposal level	Waste minimization				
			Source reduction		Recycling		Total
			Education	Backyard compost	Compost	MRF	
1	100%	sanitary landfill	0%	0%	0%	0%	0%
2	80-100%	phased development	2.5%	0%	0%	0%	2.5%
3	80-100%	phased development	15%		0%	0%	15%
4	80-100%	phased development	15%		10%	0%	25%
5	80-100%	phased development	15%		10%	15%	40%

Note: ratios of waste minimization mean of waste amount being subject for respective waste minimization measures, not of minimized waste amount.

8.3.2.2 Waste Streams of the Alternative Scenarios

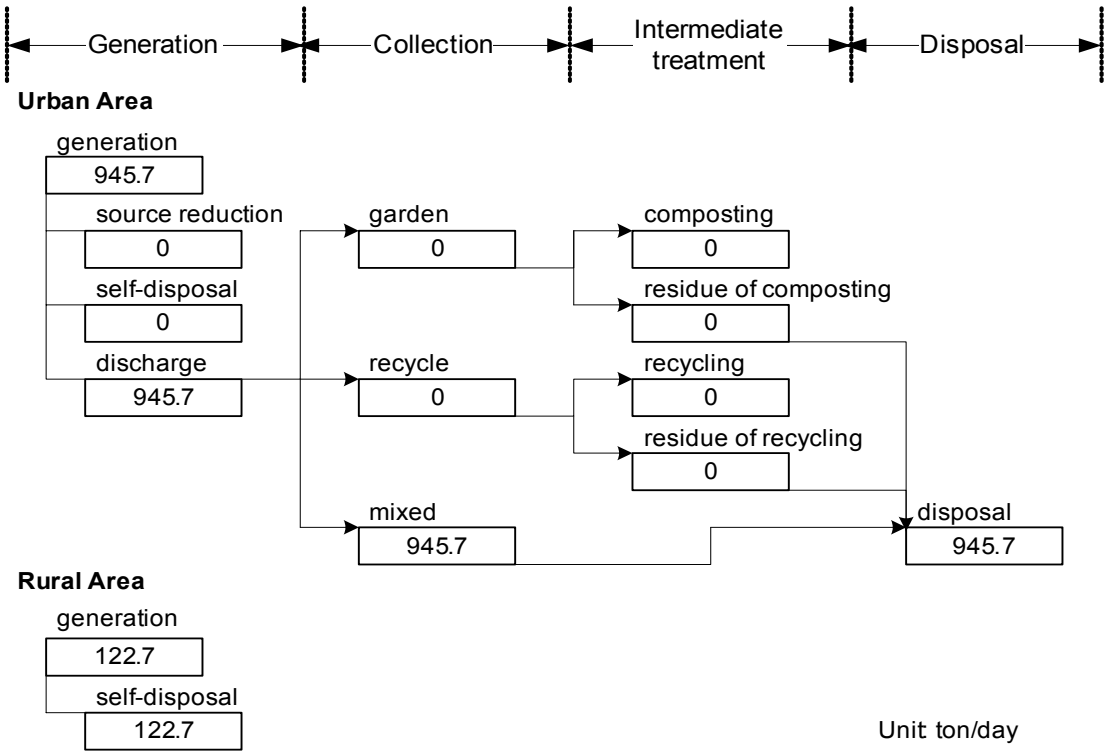
This section presents waste streams of the alternative scenarios.

a. Waste Stream of without the Master Plan



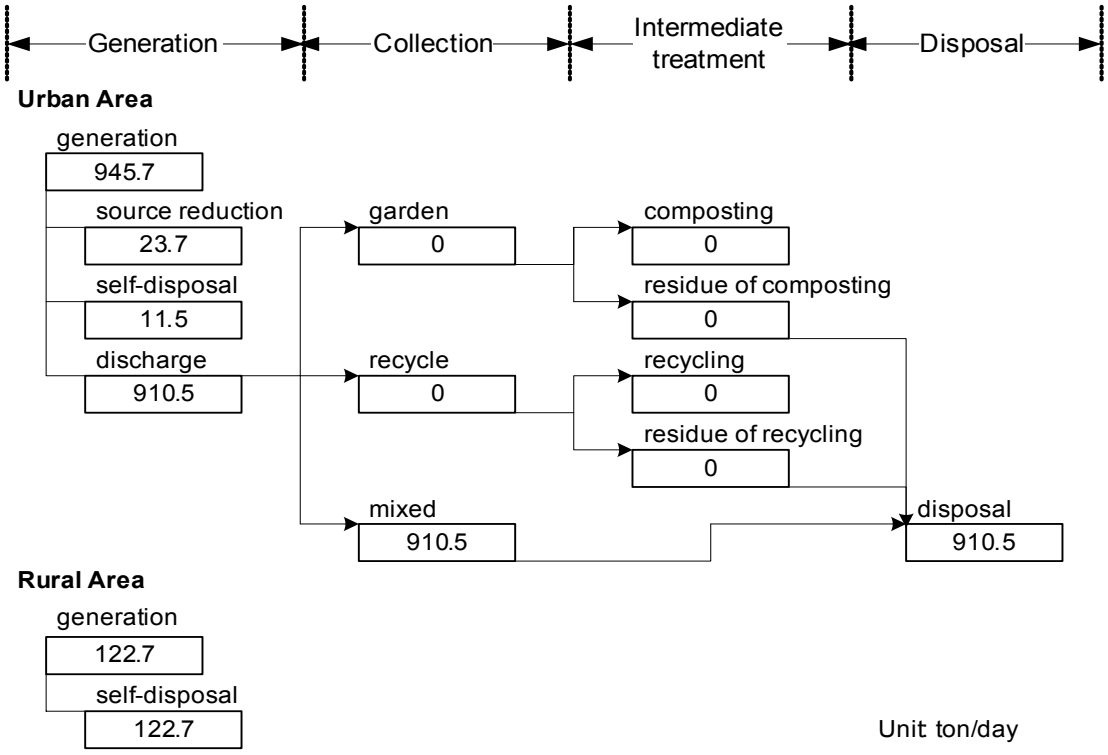
Unit: ton/day

b. Waste Stream of Scenario 1

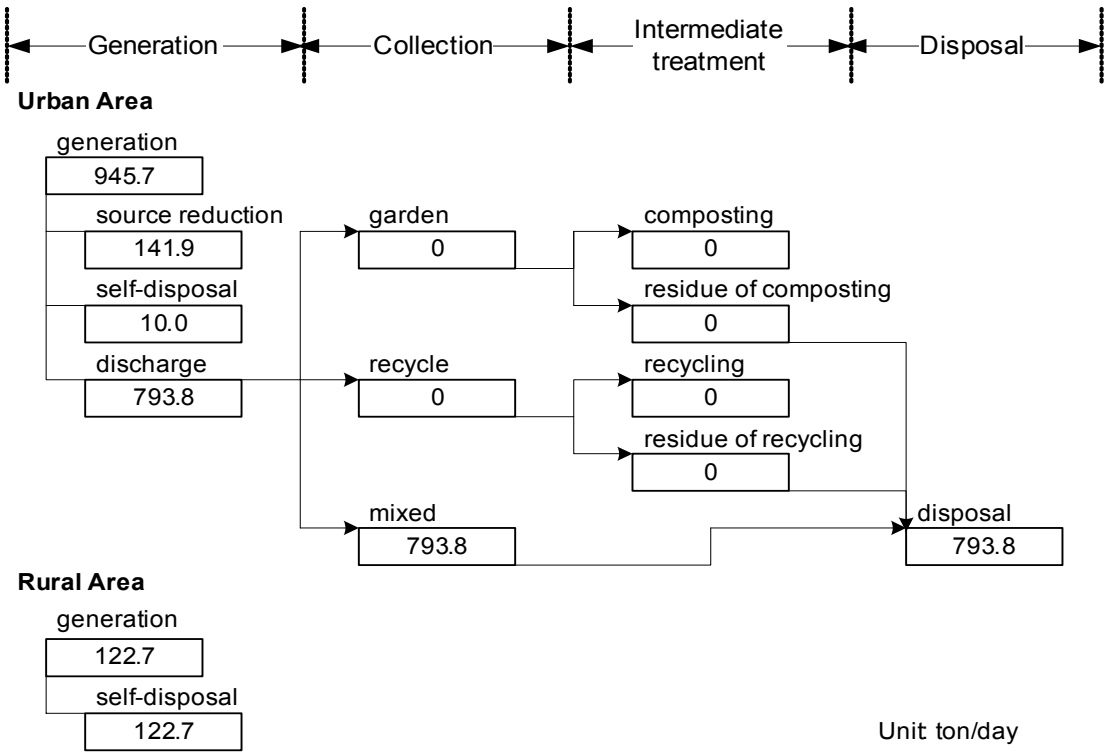


Unit: ton/day

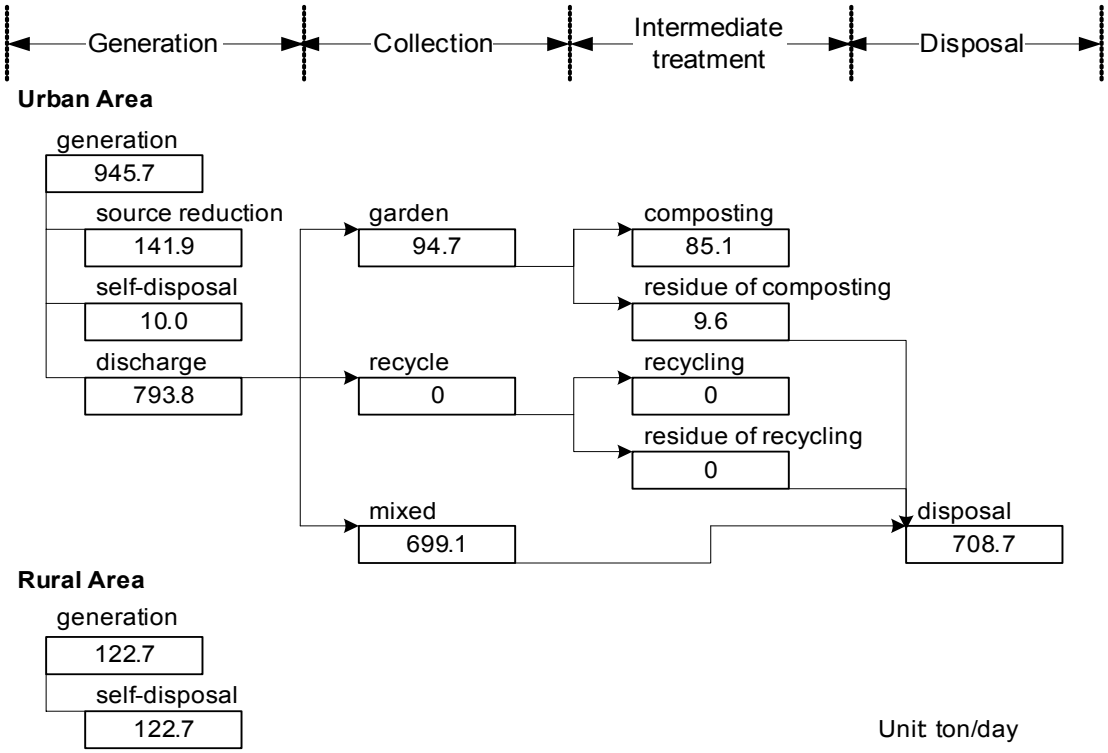
c. Waste Stream of Scenario 2



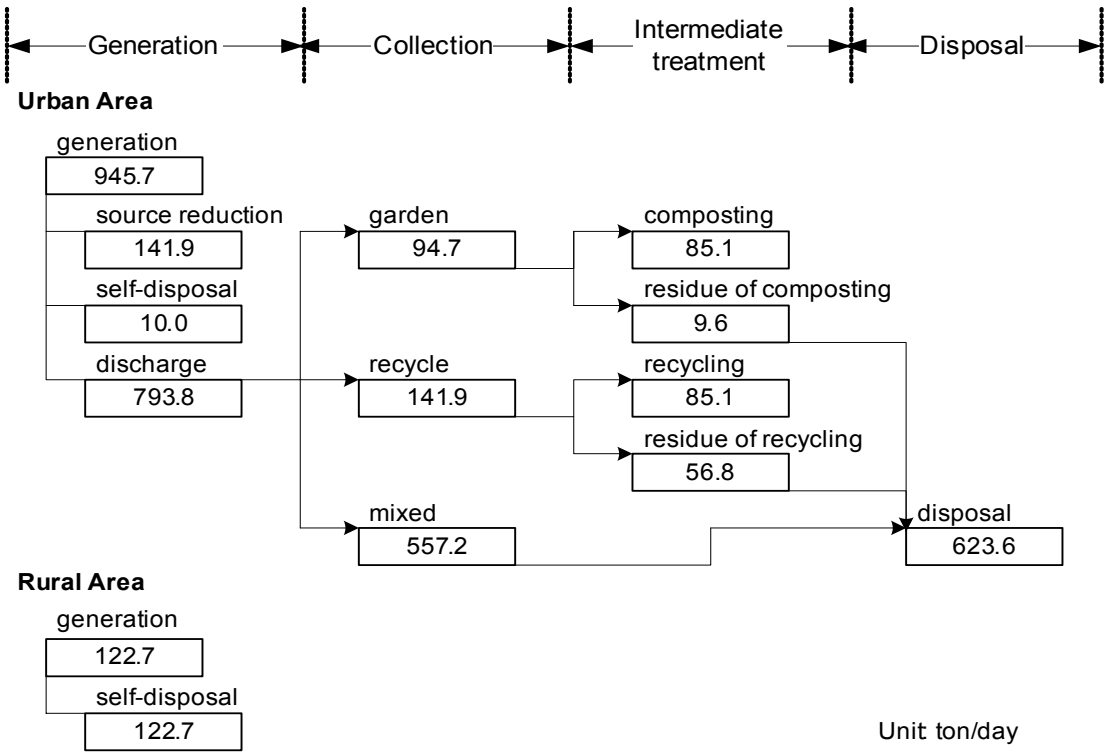
d. Waste Stream of Scenario 3



e. Waste Stream of Scenario 4



f. Waste Stream of Scenario 5



8.3.3 Selection of an Optimum System

a. Evaluation of the Alternative Scenarios

The table below shows evaluation of the Alternative Scenarios.

Table 8-21: Evaluation of the Alternative Scenarios

Evaluation items	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
1. Principal objective	All of the scenarios comply with the target value; less than 2,100 ton/year of BOD discharge amount.				
BOD (ton/year)	1,475	1,854	1,803	1,772	1,744
2. Particular objectives 1) Provision of sanitary living environment	100% of collection rate is assumed. It provides high level of sanitary living environment, but it would be excessive service.	Collection rate from 80 to 100% is supposed to be adopted depending on population size of communities. The lager population of a community, the higher collection rate is employed. Although lower level of sanitary living environment is achieved compared with Scenario 1, it will be sufficient to keep the living environment.			
Collection rate (urban area)	100%	99%	99%	99%	99%
Collection rate (whole area)	89%	87%	86%	86%	86%
2) Mitigation of environmental impact caused by waste	All of disposal sites are supposed to be sanitary landfill, even for small communities. It would be excessive measures.	Different disposal levels are supposed to be adopted depending on population size of communities, i.e., from controlled dumping to sanitary landfilling. Although lower level of mitigation of environmental impact is achieved compared with Scenario 1, it will be sufficient not to give serious impact on the environment.			
3) Resource conservation	No measure of waste minimization is to be adopted.	Only environmental education is to be adopted	Backyard compost is to be adopted in addition to the environmental education.	Compost of pruning waste is introduced in addition to measures of Scenario 3.	Material Recovery is to be introduced in addition to measures of Scenario 4.
Waste minimization rate	0% [a] (0%) [b]	2.5% [a] (2.5%) [b]	15% [a] (15%) [b]	25% [a] (24%) [b]	40% [a] (33%) [b]
3. Financial aspect	Ratios between estimated costs of all scenarios and household income are well within the benchmark ranging from 0.5% to 1.3% for middle income countries.				
1000 USD/year	13,927	13,086	11,927	12,632	14,065
Cost/Hhold. Income	0.69%	0.65%	0.59%	0.63%	0.70%
4. Legal system	The new federal law, “General Law for the Prevention and Integral Management of Waste,” aims to prevent generation of waste and recycle materials. Therefore, higher target value of waste minimization meets the objective of the law.				
5. Institutional system	Close relationship among institutions such as federal, state and municipal governments are required to achieve a certain level of final disposal and to encourage waste minimization.				
6. Management system	High capability of executing agencies (municipalities) is required for appropriately managing final disposal and waste minimization. Especially, sanitary landfills for small communities are difficult to operate in views of engineering and finance.				
7. Private sector participation	There would be opportunities where public and private sectors could cooperate in SWM. In order to introduce the private sector, the pubic sector should have enough capability to control them to provide adequate services to the citizens.				
8. Citizen participation	Waste minimization requires citizen’s positive participation in SWM, such as adequate discharge of waste, backyard composting, separation and recycling of waste.				

a: ratios of waste amount being subject for minimization measures.
b: ratios of waste amount minimized.

b. Selection of an Optimum Scenario

The Mexican counterpart and the Study Team had discussions for selecting an optimum scenario. Consequently, Scenario 4 was selected as the optimum scenario.

Table 8-22: Selected SWM Technical System

Technical System	Scenario 4
1. Source Reduction	Source reduction; by backyard composting, recycling of papers and others, and change of consumption behavior by environmental education
2. Collection and Transport	80 - 100% of collection rate depending on population size of community
3. Intermediate Treatment	Pruning waste composting
4. Final Disposal	Different disposal levels depending on population size of community

Chapter 9

The Master Plan

9 The Master Plan

9.1 Basic Concept

9.1.1 Guiding Principle, Principal Objective and Basic Approach

The Master plan intends to integrate all efforts of the public sector, the private sector, residents and visitors under the following shared values.

a. Guiding Principle

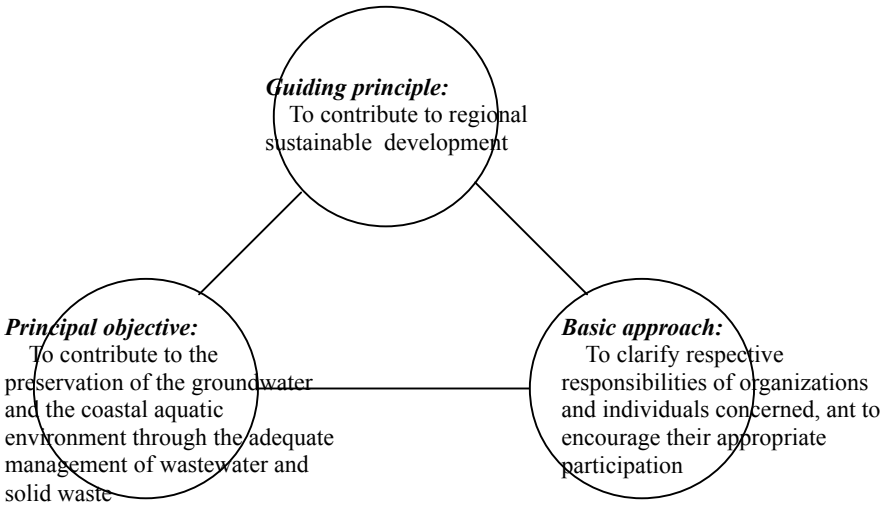
To contribute to regional sustainable development of Yucatan Peninsula

b. Principal Objective

To preserve the groundwater and the coastal aquatic environment in the southern Quintana Roo State, or municipalities of Othon P Blanco, Felipe C Puerto and Solidaridad, through the adequate management of wastewater and solid waste

c. Basic Approach

To clarify respective responsibilities of the public sector, the private sector, the residents and the tourists, and to encourage their appropriate participation in the Environmental Sanitation Management



9.1.2 Targeted Value of the Master Plan

Targeted value of the principal objective of the Master Plan is:

BOD discharge amount originated from wastewater and solid waste is to be less than 5,200 ton/year by 2015, aiming at controlling BOD concentration of the groundwater 1.0 mg/litter and below.

Less than 3,100 ton/year from wastewater, and

Less than 2,100 ton/year from solid waste.

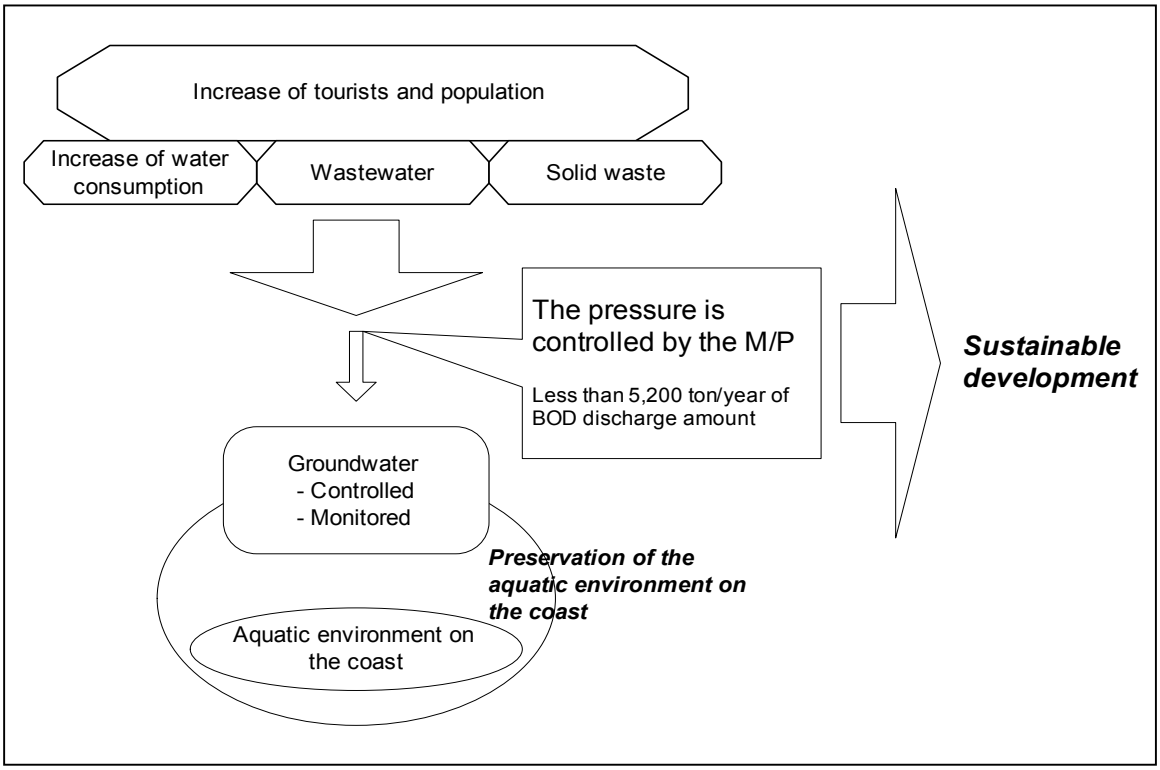


Figure 9-1: Targeted Value of the Master Plan

9.2 Wastewater Management Master Plan

9.2.1 Objectives, Targeted Values and Targeted Year

a. Principal Objective and Targeted Value

The principal objective of the Wastewater Management (WWM) Master Plan is;

To preserve the groundwater and the coastal aquatic environment in the study area

Targeted value is;

BOD discharge amount originated from wastewater is to be around 3,100 ton/year by 2015.

b. Particular Objectives and Targeted Values

A master plan formulated should aim at achieving the principal objective, in addition, at accomplishing the following particular objective inherent to wastewater management.

Reduction of health risks of the residents through employment of appropriate technology

In order to accomplish the objective, target values regarding sewer service coverage and treated water quality as shown in Table 9-1 and Table 9-2 have been set.

Table 9-1: Targeted Values of the Wastewater Management Master Plan

Items	*Municipalities*	*Present*	*Goals in 2015*
Number of connection	*Othón P. Blanco*	*10,288*	*98,330*
	Felipe Carrillo Puerto	*114*	*14,562*
	Solidaridad	*1,770*	*107,059*
Sewer system served population (permanent population basis)	*Othón P. Blanco*	*37,044*	*413,971*
	Felipe Carrillo Puerto	*567*	*72,429*
	Solidaridad	*6,655*	*402,529*
Sewer system service coverage ratio (sewer line& treatment, population basis)	*Othón P. Blanco*	*16.2%*	*99.7%*
	Felipe Carrillo Puerto	*0.9%*	*98.0%*
	Solidaridad	*4.7%*	*99.7%*

Table 9-2: Target Treatment Level by Community Size

Treatment level	Population size of community	Target treated water quality	
		BOD (mg/liter)	SS (mg/liter)
Level 1	100 to 1,499	150	125
Level 2	1,500 to 9,999	75	75
Level 3	10,000 to 49,999	50	50
Level 4	More than 50,000	30	40

c. Target Year

The target year for master plan is set up as: ***Year 2015***

9.2.2 Proposed Measures

9.2.2.1 Wastewater Treatment Method

Treatment methods shown in Table 9-3 are proposed to achieve the treatment levels set in Table 9-2.

Table 9-3: Proposed Treatment Method

Treatment level	Population size of community	Treatment method
Level 1	100 to 1,499	An-aerobic reactor + disinfection
Level 2	1,500 to 9,999	An-aerobic reactor + aerobic filter + disinfection
Level 3	10,000 to 49,999	Oxidation ditch + disinfection
Level 4	More than 50,000	Activated sludge + disinfection

9.2.2.2 Sludge Management Plan

Excess sludge will be generated in large quantity in the future along with expansion of wastewater treatment. And measures to cope with the excess sludge need to be taken. Table 9-4 shows excess sludge amount to be disposed of, which has 85% of water content.

Table 9-4: Required Excess Sludge Disposal Amount

Unit: m^3/year

	OTHON P. BLANCO				FELIPE CARRILLO PUERTO			SOLIDARIDAD			
Year	Level 1	Level 2	Level 3	Level 4	Level 1	Level 2	Level 3	Level 1	Level 2	Level 3	Level 4
2003	0	0	0	6,947	0	0	107	0	0	0	19,733
2004	0	0	0	6,947	0	0	107	0	0	0	19,733
2005	0	0	0	12,167	0	0	393	0	0	0	22,487
2006	133	487	1,367	16,600	0	0	700	0	0	1,613	27,540
2007	260	967	2,733	21,033	0	0	1,007	0	0	3,233	32,600
2008	393	1,453	4,100	25,467	0	0	1,313	0	0	4,847	37,653
2009	520	1,940	5,467	29,900	0	0	1,620	0	0	6,460	42,193
2010	1,173	2,420	6,827	34,340	327	440	1,927	173	0	8,073	47,767
2011	1,820	3,873	7,320	35,380	867	880	2,233	347	347	8,673	50,153
2012	2,473	5,327	7,807	36,420	1,413	1,313	2,547	520	693	9,267	52,547
2013	3,120	6,780	8,293	37,467	1,953	1,753	2,853	693	1,040	9,867	54,933
2014	3,773	8,233	8,780	38,507	2,500	2,193	3,160	947	1,387	10,460	57,320
2015	5,073	10,167	9,273	39,547	3,040	3,073	3,467	1,207	1,740	11,060	59,707
Total	18,740	41,647	61,967	340,720	10,100	9,653	21,433	3,887	5,207	73,553	524,367

Disposal measures of excess sludge are landfilling, desiccation and incineration. Desiccation and incineration requires large investment and sophisticated technology. Such measures are considered not suitable for the Study Area. Therefore, it is recommendable to landfill the excess sludge after dewatering.

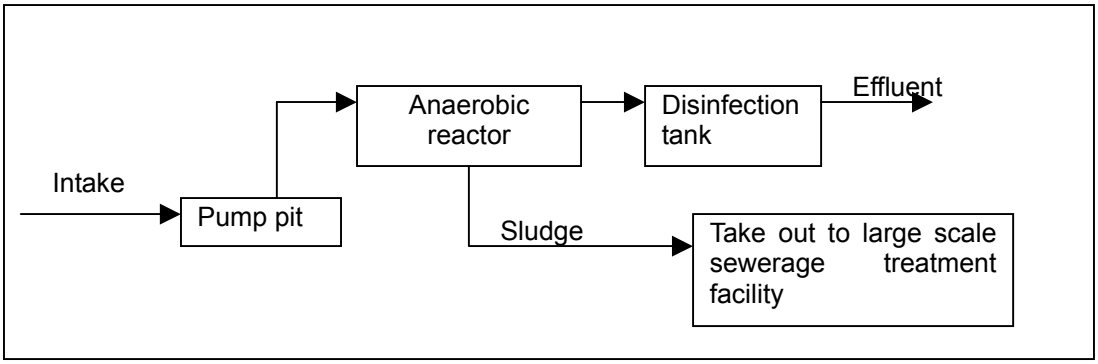
9.2.3 Treatment Process Design

9.2.3.1 Level 1

Recommended treatment method at Level 1 is the anaerobic reactor. Design conditions and treatment process flow sheet are shown below.

Table 9-5: Design Conditions and Treatment Process Flow Sheet of Level 1

Item	Number
Treatment method	Anaerobic reactor
Applicable population size (nos. of population)	100 to1,499
Wastewater generation rate (liter/person/day)	173
Intake BOD concentration (mg/liter)	312
BOD-Anaerobic reactor Load (g/m^3/day)	250
Detention time of disinfection tank (minute)	15
Sludge generation rate (m^3/person/year)	0.04
Sludge detention period (year)	3
Treated water quality (mg/liter)	BOD:150, SS:125



The table below shows required volume of reactor, based on the above conditions.

Table 9-6: Outline of Design Calculation

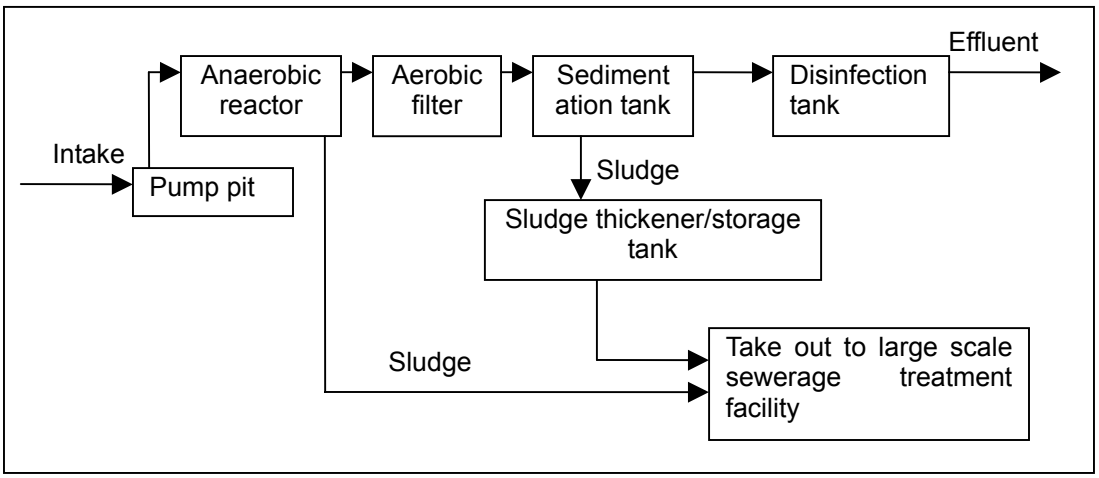
Population size	Wastewater amount (m^3/day)	Anaerobic reactor			
		Intake BOD amount (g/day)	Volume for treatment (m^3)	Volume for sludge storage (3 year sludge volume(m^3)	Total required (m^3)
100	17	5,305.7	21.2	12	33.2
250	43	13,420.3	53.7	30	83.7
500	87	27,152.7	108.6	60	168.6
750	130	40,573.0	162.3	90	252.3
1,499	259	80,833.9	323.3	180	503.3

9.2.3.2 Level 2

Recommended treatment method at Level 2 is anaerobic reactor and aerobic filter. Design conditions and treatment process flow sheet are shown below.

Table 9-7: Design Conditions and Treatment Process Flow Sheet of Level 2

Item	Number
General	
Treatment method	Anaerobic rector and aerobic filter
Applicable population size (nos. of population)	1,500 to9,999
Wastewater generation rate (liter/person/day)	173
Intake BOD concentration (mg/liter)	312
Intake SS concentration (mg/liter)	300
Treated water BOD concentration (mg/liter)	75
Treated water SS concentration (mg/liter)	75
Bio-reactor	
BOD-Anaerobic reactor Load (g/m^3/day)	250
BOD-Aerobic filter Load (kg/m^3/day)	0.8
Filter media filling rate	More than 80%
Sedimentation tank	
Hydraulic surface load (m^3/m^2/day)	25
Hydraulic over flow weir load (m^3/m/day)	30
Detention time (hr)	4.5
Disinfection tank	
Detention time (minute)	15
Sludge management	
Sludge generation amount kg/day)	50% of BOD removal amount plus 95% of SS removal amount
Moisture contents of raw sludge	99%
Moisture contents of thickened sludge	98%
Thickener	
Sludge (dry solid) surface load (kg/m^2/day)	90
Detention time (hr)	12
Thickened sludge storage tank	
Detention time (day)	7
Detention time of disinfection tank (minute)	15



The table below shows required volume of reactors based on the above conditions.

Table 9-8: Outline of Design Calculation

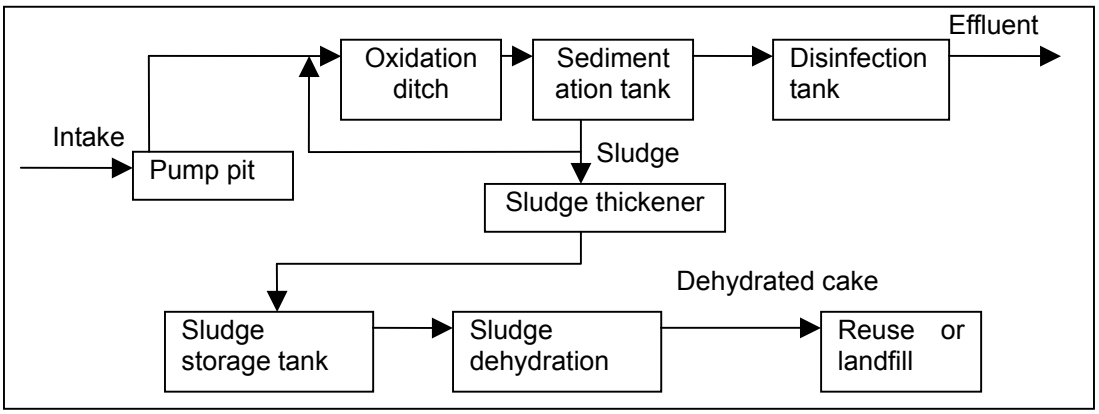
Population size	1,500	2,500	5,000	7,500	9,999
Intake amount (m^3/day)	260.0	433.0	865.0	1,298.0	1,730.0
BOD intake amount (g/day)	81,146.0	135,139.3	269,966.5	405,105.8	539,933.0
Anaerobic reactor					
Volume 1 treatment(m^3)	324.6	540.6	1,079.9	1,620.4	2,159.7
Volume2 sludge 3 year (m^3)	60.0	100.0	200.0	300.0	400.0
Total volume (m^3)	384.6	640.6	1,279.9	1,920.4	2,559.7
Detention time(day)	1.2	1.2	1.2	1.2	1.2
Aerobic filter					
BOD conc.(mg/liter)	150.0	150.0	150.0	150.0	150.0
BOD in (kg/day)	39.0	65.0	129.8	194.7	259.5
Required volume (m^3)	48.8	81.3	162.3	243.4	324.4
Detention time (hr)	4.5	4.5	4.5	4.5	4.5
Sedimentation					
Surface load (m^3/m^2/day)	25.0	25.0	25.0	25.0	25.0
Required area (m^2)	10.4	17.3	34.6	51.9	69.2
Detention time (hr)	3.0	3.0	3.0	3.0	3.0
Volume (m^3)	32.5	54.1	108.1	162.3	216.3
Depth (m)	3.1	3.1	3.1	3.1	3.1
Weir length (m)	8.7	14.4	28.8	43.3	57.7
Sludge					
Inflow aerobic BOD (mg/liter)	150	150	150	150	150
Inflow aerobic SS (mg/liter)	125	125	125	125	125
Effluent BOD (mg/liter)	75	75	75	75	75
Effluent SS(mg/liter)	75	75	75	75	75
BOD removal amount (kg/day)	19.5	32.5	64.9	97.4	129.8
SS removal amount (kg/day)	13.0	21.7	43.3	64.9	86.5
From BOD (kg/day)	9.8	16.3	32.5	48.7	64.9
From SS (kg/day)	12.4	20.6	41.1	61.7	82.2
Total (kg/day)	22.2	36.9	73.6	110.4	147.1
Sludge volume of (water contents 99%) (m^3)	2.2	3.7	7.4	11.0	14.7
Sludge volume of (water contents 98%) (m^3)	1.1	1.8	3.7	5.5	7.4
Thickener/storage thank					
Detention time (day)	7.0	7.0	7.0	7.0	7.0
Required volume (m^3)	7.7	12.6	25.9	38.5	51.8

9.2.3.3 Level 3

Recommended treatment method at Level 3 is oxidation ditch. Design conditions and treatment process flow sheet are shown below.

Table 9-9: Design Conditions and Treatment Process Flow Sheet of Level 3

Item	Number
General	
Treatment method	Oxidation ditch
Applicable population size (nos. of population)	10,000 to 49,999
Wastewater generation rate (liter/person/day)	173
Intake BOD concentration (mg/liter)	312
Intake SS concentration (mg/liter)	300
Treated water BOD concentration (mg/liter)	50
Treated water SS concentration (mg/liter)	50
Grit Chamber & pump pit	
Coefficient of hydraulic design	$M=1+(14/(4+P^{0.5})$
Hydraulic surface load (m^3/m^2/day)	1,800
Pump pit detention time (min.)	10
Oxidation ditch	
MLSS concentration (mg/liter)	4,000
BOD-MLSS Load (BOD-kg/MLSS-kg/day)	0.05
Sedimentation tank	
Hydraulic surface load (m^3/m^2/day)	25
Hydraulic over flow weir load (m^3/m/day)	30
Detention time (hr)	6.0
Disinfection tank	
Detention time (minute)	15
Sludge management	
Sludge generation amount (kg/day)	50% of BOD removal amount plus 95% of SS removal amount
Moisture contents of raw sludge	99%
Moisture contents of thickened sludge	98%
Thickener	
Sludge (dry solid) surface load (kg/m^2/day)	90
Detention time (hr)	12
Thickened sludge storage tank	
Detention time (day)	3
Detention time of disinfection tank (minute)	15
Sludge dehydration	
Type of sludge dehydrator	Belt filter press
Filtration rate (kg-SS/m)	120



The table below shows required volume of reactors based on above conditions.

Table 9-10: Outline of Design Calculation

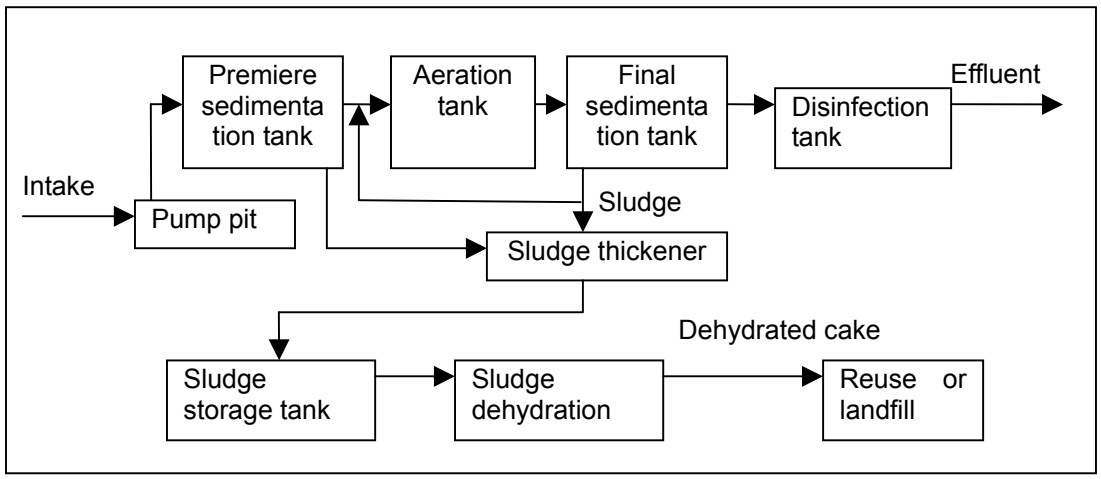
Population size	10,000	20,000	30,000	40,000	49,999
Intake amount (m^3/day)	1,730.0	3,460.0	5,190.0	6,920.0	8,650.0
BOD intake (g/day)	539,933	1,079,866	1,619,799	2,159,732	2,699,665
Grit Chamber					
Coefficient (M)	3.0	2.7	2.5	2.4	2.3
Design flow amount (m^3/day)	5,104.0	9,169.0	12,871.0	16,331.0	19,549.0
Required surface area (m^2)	2.8	5.1	7.2	9.1	10.9
Required pump pit volume (m^3)	35.4	63.7	89.4	113.4	135.8
Oxidation ditch					
BOD-SS load (kg/kg/day)	0.1	0.1	0.1	0.1	0.1
MLSS (mg/liter)	4,000.0	4,000.0	4,000.0	4,000.0	4,000.0
Required volume (m^3)	2,699.7	5,399.3	8,099.0	10,798.7	13,498.3
Detention time	37.5	37.5	37.5	37.5	37.5
Sedimentation tank					
Surface load (m^3/m^2/day)	12.0	12.0	12.0	12.0	12.0
Required area (m^2)	144.2	288.3	432.5	576.7	720.8
Detention time (hr)	6.0	6.0	6.0	6.0	6.0
Required volume (m^3)	432.5	865.0	1,297.5	1,730.0	2,162.5
Depth (m)	3.0	3.0	3.0	3.0	3.0
Disinfection tank					
Detention time (min)	15.0	15.0	15.0	15.0	15.0
Required volume (m^3)	18.0	36.0	54.1	72.1	90.1
Sludge management					
Effluent BOD conc. (mg/liter)	50.0	50.0	50.0	50.0	50.0
Effluent SS conc.(mg/liter)	50.0	50.0	50.0	50.0	50.0
BOD remove amount(kg/day)	453.3	906.5	1,359.8	1,813.0	2,266.3
SS remove amount(kg/day)	432.5	865.0	1,297.5	1,730.0	2,162.5
Dry solid from SS (kg/day)	226.7	453.3	679.9	906.5	1,133.2
Dry solid from BOD (kg/day)	410.9	821.8	1,232.6	1,643.5	2,054.4
Sludge amount (DS-kg/day)	637.6	1,275.1	1,912.5	2,550.0	3,187.6
Sludge volume of (water contents 99%) (m^3)	63.8	127.5	191.3	255.0	318.8
Sludge volume of (water contents 98%) (m^3)	31.9	63.8	95.6	127.5	159.4
Thickener					
Solid load (kg/m^2/day)	90.0	90.0	90.0	90.0	90.0
Required area (m^2)	7.1	14.2	21.3	28.3	35.4
Detention time (hr)	12.0	12.0	12.0	12.0	12.0
Required volume (m^3)	31.9	63.8	95.7	127.5	159.4
Sludge storage thank					
Detention time (days)	3.0	3.0	3.0	3.0	3.0
Required volume (m3)	95.7	191.4	286.8	382.5	478.2
Sludge dehydration					
Filtration rate (kg/m/h)	120.0	120.0	120.0	120.0	120.0
Operation time (hr)	8.0	8.0	8.0	8.0	8.0
Treatment amount (kg/hr)	79.7	159.4	239.1	318.8	398.5
Required belt wide (m)	0.7	1.3	2.0	2.7	3.3
Nos. of equipment	1.0	1.0	2.0	2.0	2.0
Use belt filter press wide (m/equipment)	0.7	1.3	1.0	1.4	1.7

9.2.3.4 Level 4

Recommended treatment method at Level 4 is activated sludge. Design conditions and treatment process flow sheet are shown below.

Table 9-11: Design Conditions and Treatment Process Flow Sheet of Level 4

Item	Number
General	
Treatment method	Conventional activated sludge method
Applicable population size (nos. of population)	50,000 to 200,000
Wastewater generation rate (liter/person/day)	173
Intake BOD concentration (mg/liter)	312
Intake SS concentration (mg/liter)	300
Treated water BOD concentration (mg/liter)	30
Treated water SS concentration (mg/liter)	40
Grit Chamber & pump pit	
Coefficient of hydraulic design	$M=1+(14/(4+P^{0.5})$
Hydraulic surface load (m^3/m^2/day)	1,800
Pump pit detention time (min.)	10
Premiere sedimentation tank	
Hydraulic surface load (m^3/m^2/day)	35
Hydraulic over flow weir load (m^3/m/day)	250
Detention time (hr)	3.0
Aeration tank	
MLSS concentration (mg/liter)	2,000
BOD-MLSS Load (BOD-kg/MLSS-kg/day)	0.3
Final sedimentation tank	
Hydraulic surface load (m^3/m^2/day)	20
Hydraulic over flow weir load (m^3/m/day)	150
Detention time (hr)	4.0
Disinfection tank	
Detention time (minute)	15
Sludge management	
Sludge generation amount (kg/day)	50% of BOD removal amount plus 95% of SS removal amount
Moisture contents of raw sludge	99%
Moisture contents of thickened sludge	98%
Thickener	
Sludge (dry solid) surface load (kg/m^2/day)	90
Detention time (hr)	12
Thickened sludge storage tank	
Detention time (day)	3
Detention time of disinfection tank (minute)	15
Sludge dehydration	
Type of sludge dehydrator	Belt filter press
Filtration rate (kg-SS/m)	120



Below table shows required volume of reactors based on above conditions.

Table 9-12: Outline of Design Calculation

Population size	50,000	75,000	100,000	150,000	200,000
Intake amount (m^3/day)	8,650.0	12,975.0	17,300.0	25,950.0	34,600.0
BOD intake (g/day)	2,699,665	4,049,498	5,399,330	8,098,995	10,798,660
Grit Chamber					
Coefficient (M)	2.3	2.1	2.0	1.9	1.8
Design flow amount (m^3/day)	19,549.0	27,377.0	34,600.0	48,267.0	61,242.0
Required surface area (m^2)	10.9	15.2	19.2	26.8	34.0
Required pump pit volume (m^3)	135.8	190.1	240.3	335.2	425.3
Premiere sedimentation tank					
BOD removal ratio (%)	30	30	30	30	30
Surface load (m^3/m^2/day)	35.0	35.0	35.0	35.0	35.0
Required area (m^2)	247.1	370.7	494.3	741.4	988.6
Detention time (hr)	3.0	3.0	3.0	3.0	3.0
Required volume (m^3)	1,081.3	1,621.9	2,162.5	3,243.8	4,325.0
Depth (m)	4.4	4.4	4.4	4.4	4.4
Outflow BOD amount (kg/day)	1,889.2	2,833.7	3,778.3	5,667.5	7,556.6
Aeration tank					
BOD-MLSS load (kg/kg/day)	0.3	0.3	0.3	0.3	0.3
MLSS (mg/liter)	2,000.0	2,000.0	2,000.0	2,000.0	2,000.0
Required volume (m^3)	3,148.7	4,722.8	6,297.2	9,445.8	12,594.3
Detention time (hr)	8.7	8.7	8.7	8.7	8.7
Depth (m)	4.0	4.0	4.0	4.0	4.0
Final sedimentation tank					
Surface load (m^3/m^2/day)	20.0	20.0	20.0	20.0	20.0
Required area (m^2)	432.5	648.8	865.0	1,297.5	1,730.0
Detention time (hr)	4.0	4.0	4.0	4.0	4.0
Required volume (m^3)	1,441.7	2,162.5	2,883.3	4,325.0	5,766.7
Depth (m)	3.3	3.3	3.3	3.3	3.3
Disinfection					
Detention time (min)	15.0	15.0	15.0	15.0	15.0
Required volume (m^3)	90.1	135.2	180.2	270.3	360.4
Sludge management					
Effluent BOD conc. (mg/liter)	30.0	30.0	30.0	30.0	30.0
Effluent SS conc.(mg/liter)	40.0	40.0	40.0	40.0	40.0
BOD remove amount(kg/day)	2,439.3	3,659.0	4,878.6	7,317.9	9,757.2
SS remove amount(kg/day)	2,249.0	3,373.5	4,498.0	6,747.0	8,996.0
Dry solid from SS (kg/day)	1,219.7	1,829.5	2,439.3	3,659.0	4,878.6
Dry solid from BOD (kg/day)	2,136.6	3,204.8	4,273.1	6,409.7	8,546.2

Population size	50,000	75,000	100,000	150,000	200,000
Sludge amount (DS-kg/day)	3,356.3	5,034.3	6,712.4	10,068.7	13,424.8
Sludge volume of (water contents 99%) (m^3)	335.6	503.4	671.2	1,006.9	1,342.5
Sludge volume of (water contents 98%) (m^3)	167.8	251.7	335.6	503.4	671.2
Thickener					
Solid load (kg/m^2/day)	90.0	90.0	90.0	90.0	90.0
Required area (m^2)	37.3	55.9	74.6	111.9	149.2
Detention time (hr)	12.0	12.0	12.0	12.0	12.0
Required volume (m^3)	167.8	251.7	335.6	503.5	671.3
Sludge storage thank					
Detention time (days)	3.0	3.0	3.0	3.0	3.0
Required volume (m3)	503.4	755.1	1,006.8	1,510.2	2,013.6
Sludge dehydration					
Filtration rate (kg/m/h)	120.0	120.0	120.0	120.0	120.0
Operation time (hr)	8.0	8.0	8.0	8.0	8.0
Treatment amount (kg/hr)	419.5	629.3	839.1	1,258.6	1,678.1
Required belt wide (m)	3.5	5.2	7.0	10.5	14.0
Nos. of equipment	2.0	2.0	3.0	4.0	5.0
Use belt filter press wide (m/equipment)	1.8	2.6	2.3	2.6	2.8

9.2.4 Cost Estimation

Cost of Master Plan is estimated as follows.

Table 9-13: Overall Coast of the Master Plan

unit: million pesos

Item	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Total
Othón P. Blanco	7.382	276.593	60.320	186.677	193.609	199.550	66.678	98.409	102.773	91.251	109.209	128.425	1,520.876
Felipe C Puerto	2.028	17.505	3.264	3.701	17.539	4.514	23.511	43.399	30.525	31.369	32.946	33.956	244.257
Solidaridad	165.711	186.520	56.711	338.476	62.655	209.531	199.490	64.701	62.171	64.418	69.171	58.874	1,538.429
Total	175.121	480.618	120.295	528.854	273.803	413.595	289.679	206.509	195.469	187.038	211.326	221.255	3,303.562

Table 9-14: Master Plan Cost in Othón P. Blanco

unit: million pesos

Item	Level	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Total
Sewer line														
Construction	Level 1	0	0	2.546	2.452	2.388	2.344	11.419	12.651	10.447	10.296	11.734	21.356	87.633
	Level 2	0	0	10.61	8.912	2.026	12.523	2.266	18.467	21.638	12.345	19.323	23.171	131.281
	Level 3	0	10.491	10.491	10.491	10.491	10.491	3.76	3.76	3.76	3.76	3.76	0	71.255
	Level 4	0	0	14.169	14.241	14.241	14.241	3.647	3.647	3.647	3.647	3.647	0	75.127
	total	0	10.491	37.816	36.096	29.146	39.599	21.092	38.525	39.492	30.048	38.464	44.527	365.296
Design & supervision	Level 1	0	0.076	0.074	0.072	0.07	0.343	0.38	0.313	0.309	0.352	0.641	0	2.63
	Level 2	0	0.318	0.267	0.061	0.376	0.068	0.554	0.649	0.37	0.58	0.695	0	3.938
	Level 3	0.315	0.315	0.315	0.315	0.315	0.113	0.113	0.113	0.113	0.113	0	0	2.14
	Level 4	0	0.425	0.427	0.427	0.427	0.109	0.109	0.109	0.109	0.109	0	0	2.251
	total	0.315	1.134	1.083	0.875	1.188	0.633	1.156	1.184	0.901	1.154	1.336	0	10.959
Operation & maintenance	Level 1	0	0	0.127	0.25	0.368	0.486	1.056	1.691	2.213	2.725	3.313	4.382	16.611
	Level 2	0	0	0.532	0.978	1.077	1.707	1.818	2.737	3.82	4.437	5.402	6.564	29.072
	Level 3	0	0	0.524	1.049	1.574	2.099	2.623	2.812	2.999	3.187	3.375	3.563	23.805
	Level 4	0.662	1.021	1.734	2.442	3.154	3.866	4.578	4.761	4.943	5.126	5.308	5.49	43.085
	total	0.662	1.021	2.917	4.719	6.173	8.158	10.075	12.001	13.975	15.475	17.398	19.999	112.573
Sewer line total		0.977	12.646	41.816	41.69	36.507	48.39	32.323	51.71	54.368	46.677	57.198	64.526	488.828
Treatment facilities														
Construction	Level 1	0	0	2.15	2.071	2.019	1.98	9.645	10.687	8.825	8.698	9.912	18.042	74.029
	Level 2	0	0	4.071	5.178	1.177	7.276	1.316	10.728	12.571	7.172	11.226	13.462	74.177
	Level 3	0	38.561	0	38.561	0	38.561	0	0	0	0	0	0	115.683
	Level 4	0	215.68	0	81.431	134.25	81.431	0	0	0	0	0	0	512.789
	total	0	254.24	6.221	127.24	137.44	129.25	10.961	21.415	21.396	15.87	21.138	31.504	776.678
Design & supervision	Level 1	0	0.065	0.062	0.061	0.059	0.289	0.321	0.265	0.261	0.297	0.541	0	2.221
	Level 2	0	0.122	0.155	0.035	0.218	0.039	0.322	0.377	0.215	0.337	0.404	0	2.224
	Level 3	0.578	0.578	0.578	0.578	0.578	0.578	0	0	0	0	0	0	3.468
	Level 4	3.235	3.235	1.221	3.235	2.014	1.221	0	0	0	0	0	0	14.161
	total	3.813	4	2.016	3.909	2.869	2.127	0.643	0.642	0.476	0.634	0.945	0	22.074
Operation & maintenance	Level 1	0	0	0.107	0.211	0.311	0.411	0.892	1.429	1.869	2.302	2.798	3.701	14.031
	Level 2	0	0	0.3	0.553	0.608	0.964	1.027	1.547	2.159	2.507	3.052	3.709	16.426
	Level 3	0	0	1.44	1.993	2.411	2.759	3.064	3.166	3.265	3.361	3.453	3.543	28.455
	Level 4	1.799	4.338	6.338	8.267	9.977	11.409	12.796	13.12	13.442	13.762	14.08	14.396	123.724
	total	1.799	4.338	8.185	11.024	13.307	15.543	17.779	19.262	20.735	21.932	23.383	25.349	182.636
Treatment facilities total		5.612	262.58	16.422	142.17	153.62	146.92	29.383	41.319	42.607	38.436	45.466	56.853	981.388
Sludge management														
Disposal cost	Level 1	0	0	0.016	0.032	0.047	0.062	0.135	0.216	0.282	0.348	0.422	0.558	2.118
	Level 2	0.029	0.031	0.09	0.166	0.183	0.29	0.309	0.467	0.651	0.757	0.921	1.118	5.012
	Level 3	0	0	0.15	0.301	0.451	0.601	0.751	0.805	0.859	0.912	0.966	1.02	6.816
	Level 4	0.764	1.338	1.826	2.314	2.801	3.289	3.777	3.892	4.006	4.121	4.236	4.35	36.714
	total	0.793	1.369	2.082	2.813	3.482	4.242	4.972	5.38	5.798	6.138	6.545	7.046	50.66
Overall														
Sewer line		0.977	12.646	41.816	41.69	36.507	48.39	32.323	51.71	54.368	46.677	57.198	64.526	488.828
Treatment facilities		5.612	262.58	16.422	142.17	153.62	146.92	29.383	41.319	42.607	38.436	45.466	56.853	981.388
Sludge management		0.793	1.369	2.082	2.813	3.482	4.242	4.972	5.38	5.798	6.138	6.545	7.046	50.66
Overall total		7.382	276.59	60.32	186.68	193.61	199.55	66.678	98.409	102.77	91.251	109.21	128.43	1,520.88

Table 9-15: Master Plan Cost in Felipe C Puerto

unit: million pesos

Item	Level	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Total
Sewer line														
Construction	Level 1	0	0	0	0	0	0	5.444	11.974	7.827	9.188	9.476	8.605	52.514
	Level 2	0	0	0	0	0	0	1.637	0.015	1.625	0.944	0.863	1.774	6.858
	Level 3	1.584	3.219	2.274	2.248	2.274	2.274	2.248	2.274	2.274	2.248	2.274	0	25.191
	Level 4	0	0	0	0	0	0	0	0	0	0	0	0	0
	total	1.584	3.219	2.274	2.248	2.274	2.274	9.329	14.263	11.726	12.38	12.613	10.379	84.563
Design & supervision	Level 1	0	0	0	0	0	0.163	0.359	0.235	0.276	0.284	0.258	0	1.575
	Level 2	0	0	0	0	0	0.049	0	0.049	0.028	0.026	0.053	0	0.205
	Level 3	0.097	0.068	0.067	0.068	0.068	0.067	0.068	0.068	0.067	0.068	0	0	0.706
	Level 4	0	0	0	0	0	0	0	0	0	0	0	0	0
	total	0.097	0.068	0.067	0.068	0.068	0.279	0.427	0.352	0.371	0.378	0.311	0	2.486
Operation & maintenance	Level 1	0	0	0	0	0	0	0.273	0.872	1.263	1.722	2.195	2.626	8.951
	Level 2	0	0	0	0	0	0	0.082	0.083	0.164	0.211	0.254	0.343	1.137
	Level 3	0.018	0.097	0.258	0.372	0.484	0.598	0.712	0.824	0.938	1.052	1.164	1.278	7.795
	Level 4	0	0	0	0	0	0	0	0	0	0	0	0	0
	total	0.018	0.097	0.258	0.372	0.484	0.598	1.067	1.779	2.365	2.985	3.613	4.247	17.883
Sewer line total		1.699	3.384	2.599	2.688	2.826	3.151	10.823	16.394	14.462	15.743	16.537	14.626	104.932
Treatment facilities														
Construction	Level 1	0	0	0	0	0	0	4.689	10.311	6.74	7.913	8.16	7.41	45.223
	Level 2	0	0	0	0	0	0	5.69	0.053	5.65	3.283	2.999	6.168	23.843
	Level 3	0	13.574	0	0	13.574	0	0	13.574	0	0	0	0	40.722
	Level 4	0	0	0	0	0	0	0	0	0	0	0	0	0
	total	0	13.574	0	0	13.574	0	10.379	23.938	12.39	11.196	11.159	13.578	109.788
Design & supervision	Level 1	0	0	0	0	0	0.141	0.309	0.202	0.237	0.245	0.222	0	1.356
	Level 2	0	0	0	0	0	0.171	0.002	0.17	0.098	0.09	0.185	0	0.716
	Level 3	0.204	0.204	0	0.204	0.204	0	0.204	0.204	0	0	0	0	1.224
	Level 4	0	0	0	0	0	0	0	0	0	0	0	0	0
	total	0.204	0.204	0	0.204	0.204	0.312	0.515	0.576	0.335	0.335	0.407	0	3.296
Operation & maintenance	Level 1	0	0	0	0	0	0	0.235	0.751	1.088	1.483	1.89	2.261	7.708
	Level 2	0	0	0	0	0	0	0.285	0.287	0.57	0.734	0.883	1.192	3.951
	Level 3	0.113	0.3	0.588	0.698	0.791	0.873	0.947	1.015	1.078	1.137	1.193	1.246	9.979
	Level 4	0	0	0	0	0	0	0	0	0	0	0	0	0
	total	0.113	0.3	0.588	0.698	0.791	0.873	1.467	2.053	2.736	3.354	3.966	4.699	21.638
Treatment facilities total		0.317	14.078	0.588	0.902	14.569	1.185	12.361	26.567	15.461	14.885	15.532	18.277	134.722
Sludge management														
Disposal cost	Level 1	0	0	0	0	0	0	0.034	0.111	0.161	0.219	0.279	0.334	1.138
	Level 2	0	0	0	0	0	0	0.081	0.081	0.161	0.208	0.25	0.338	1.119
	Level 3	0.012	0.043	0.077	0.111	0.144	0.178	0.212	0.246	0.28	0.314	0.348	0.381	2.346
	Level 4	0	0	0	0	0	0	0	0	0	0	0	0	0
	total	0.012	0.043	0.077	0.111	0.144	0.178	0.327	0.438	0.602	0.741	0.877	1.053	4.603
Overall														
Sewer line		1.699	3.384	2.599	2.688	2.826	3.151	10.823	16.394	14.462	15.743	16.537	14.626	104.932
Treatment facilities		0.317	14.078	0.588	0.902	14.569	1.185	12.361	26.567	15.461	14.885	15.532	18.277	134.722
Sludge management		0.012	0.043	0.077	0.111	0.144	0.178	0.327	0.438	0.602	0.741	0.877	1.053	4.603
Overall total		2.028	17.505	3.264	3.701	17.539	4.514	23.511	43.399	30.525	31.369	32.946	33.956	244.257

Table 9-16: Master Plan Cost in Solidaridad

unit: million pesos

Item	Level	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Total
Sewer line														
Construction	Level 1	0	0	0	0	0	0	3.395	3.358	3.016	3.085	2.954	3.878	19.686
	Level 2	0	0	0	0	0	0	0	0.867	0.045	0.045	0.708	0.594	2.259
	Level 3	0	11.438	11.438	11.438	11.438	11.438	4.174	4.174	4.174	4.174	4.174	0	78.06
	Level 4	9.38	20.291	20.383	20.383	18.498	22.176	9.186	9.186	9.186	9.186	9.186	0	157.041
	total	9.38	31.729	31.821	31.821	29.936	33.614	16.755	17.585	16.421	16.49	17.022	4.472	257.046
Design & supervision	Level 1	0	0	0	0	0	0.102	0.101	0.09	0.093	0.089	0.116	0	0.591
	Level 2	0	0	0	0	0	0	0.026	0.001	0.001	0.021	0.018	0	0.067
	Level 3	0.343	0.343	0.343	0.343	0.343	0.126	0.126	0.126	0.126	0.126	0	0	2.345
	Level 4	0.608	0.611	0.611	0.555	0.665	0.276	0.276	0.276	0.276	0.276	0	0	4.43
	total	0.951	0.954	0.954	0.898	1.008	0.504	0.529	0.493	0.496	0.512	0.134	0	7.433
Operation & maintenance	Level 1	0	0	0.05	0.052	0.053	0.055	0.216	0.374	0.516	0.661	0.801	0.984	3.762
	Level 2	0	0	0.019	0.021	0.024	0.026	0.028	0.061	0.062	0.064	0.091	0.113	0.509
	Level 3	0	0	0.572	1.144	1.716	2.287	2.859	3.068	3.277	3.486	3.694	3.903	26.006
	Level 4	3.63	4.099	5.114	6.133	7.152	8.077	9.186	9.644	10.104	10.563	11.023	11.482	96.207
	total	3.63	4.099	5.755	7.35	8.945	10.445	12.289	13.147	13.959	14.774	15.609	16.482	126.484
Sewer line total		13.961	36.782	38.53	40.069	39.889	44.563	29.573	31.225	30.876	31.776	32.765	20.954	390.963
Treatment facilities														
Construction	Level 1	0	0	0	0	0	0	2.8	2.767	2.487	2.543	2.435	3.198	16.23
	Level 2	0	0	0	0	0	0	0	3.301	0.172	0.171	2.696	2.262	8.602
	Level 3	0	38.734	0	38.734	0	38.734	0	0	0	0	0	0	116.202
	Level 4	138.94	98.931	0	237.87	0	98.931	138.94	0	0	0	0	0	713.598
	total	138.94	137.67	0	276.6	0	137.67	141.74	6.068	2.659	2.714	5.131	5.46	854.632
Design & supervision	Level 1	0	0	0	0	0	0.084	0.083	0.075	0.076	0.073	0.096	0	0.487
	Level 2	0	0	0	0	0	0	0.099	0.005	0.005	0.081	0.068	0	0.258
	Level 3	0.581	0.581	0.581	0.581	0.581	0.581	0	0	0	0	0	0	3.486
	Level 4	3.568	1.484	3.568	3.568	1.484	3.568	2.084	0	0	0	0	0	19.324
	total	4.149	2.065	4.149	4.149	2.065	4.233	2.266	0.08	0.081	0.154	0.164	0	23.555
Operation & maintenance	Level 1	0	0	0.041	0.043	0.044	0.045	0.178	0.308	0.425	0.545	0.661	0.812	3.102
	Level 2	0	0	0.071	0.08	0.09	0.098	0.108	0.231	0.238	0.244	0.345	0.43	1.935
	Level 3	0	0	1.24	1.717	2.077	2.377	2.639	2.726	2.809	2.888	2.966	3.041	24.48
	Level 4	6.47	7.506	9.443	11.841	13.777	15.157	16.783	17.461	18.132	18.796	19.455	20.11	174.931
	total	6.47	7.506	10.795	13.681	15.988	17.677	19.708	20.726	21.604	22.473	23.427	24.393	204.448
Treatment facilities total		149.55	147.24	14.944	294.43	18.053	159.58	163.71	26.874	24.344	25.341	28.722	29.853	1,082.64
Sludge management														
Disposal cost	Level 1	0.007	0.007	0.007	0.007	0.007	0.007	0.029	0.051	0.07	0.089	0.108	0.133	0.522
	Level 2	0.018	0.021	0.024	0.028	0.031	0.034	0.037	0.08	0.082	0.084	0.12	0.149	0.708
	Level 3	0	0	0.177	0.356	0.533	0.711	0.888	0.954	1.019	1.085	1.151	1.217	8.091
	Level 4	2.171	2.474	3.029	3.586	4.142	4.641	5.254	5.517	5.78	6.043	6.305	6.568	55.51
	total	2.196	2.502	3.237	3.977	4.713	5.393	6.208	6.602	6.951	7.301	7.684	8.067	64.831
Overall														
Sewer line		13.961	36.782	38.53	40.069	39.889	44.563	29.573	31.225	30.876	31.776	32.765	20.954	390.963
Treatment facilities		149.55	147.24	14.944	294.43	18.053	159.58	163.71	26.874	24.344	25.341	28.722	29.853	1,082.64
Sludge management		2.196	2.502	3.237	3.977	4.713	5.393	6.208	6.602	6.951	7.301	7.684	8.067	64.831
Overall total		165.71	186.52	56.711	338.48	62.655	209.53	199.49	64.701	62.171	64.418	69.171	58.874	1,538.43

9.2.5 Financial Analysis of Wastewater Master Plan

9.2.5.1 Considerations on Income Sources

Possible income sources considered for wastewater treatment were (1) service charges from wastewater treatment, (2) surplus of water supply income, and (3) contribution of the tour industry. Income was estimated based on the number of residents plus the number of tourists and their period of stay or visit ("tourist/day"), their water consumption and their wastewater generation.

The data on income per cubic meter was obtained from the CAPA financial results during the first nine months of 2003, which indicated 7.11 Pesos per cubic meter of drinking water, and 1.42 Pesos per cubic meter of wastewater treatment. The income per cubic meter of wastewater treatment was equivalent to 20% of the income per cubic meter of water supply, probably based on the wastewater treated at present as a proportion of water consumption. Then, the income per cubic meter of wastewater treatment should increase in the same way as the increasing treatment of wastewater as a proportion of water consumption up to 75% in 2011 and thereafter, as indicated in the following Table.

Table 9-17: Wastewater Treatment Achievement Ratio and Assumed Treatment

Year	Wastewater Treatment Achievement Ratio (%)	Assumed treated wastewater / water consumed (%)
2003	17.5	20
2004	17.6	20
2005	22.9	25
2006	31.8	35
2007	40.8	45
2008	49.4	50
2009	58.2	60
2010	68.8	70
2011	74.9	75
2012	81.1	75
2013	86.6	75
2014	92.8	75
2015	100.0	75

The upper bound of treated wastewater was assumed to be 75% of water consumed.

In order to estimate the surplus of water supply income as the second source of income for the Wastewater Master Plan, the cost of production of drinking water was estimated to be 90% of gross income of water supply according to the analysis of CAPA Income Statement of 2002, and 95% according to the Income Statements of 2000 and 2001.

Water consumption was assumed to be 230 l/c/d, as per CNA directives for hot climate.

As the third income source for the implementation of the Wastewater Master Plan, the tour industry was assumed to share in the cost of the Wastewater Master Plan according to the percentage of water consumption by tourists.

9.2.5.2 Financial Analysis

a. Income and Cost of Wastewater Master Plan

Estimation of income from the three sources considered in this analysis resulted in the following Table showing possible income levels in relation to the cost of Wastewater Master Plan.

Table 9-18: Income by Source and Wastewater Master Plan Cost by Municipality

Unit: Million Pesos

Income Source	OPB	FCP	Solidaridad	Study Area
Wastewater Income Only	1,170.07	130.75	2,847.86	4,148.67
Water Supply Income Surplus (WS expenses = 90% of gross income)	176.93	18.23	439.16	634.31
Water Supply Income Surplus (WS expenses = 95% of gross income)	88.46	9.11	219.58	317.16
Tour Industry Share in the Cost of Wastewater Treatment Master Plan	34.41	0	142.37	176.78
Cost of the Wastewater Master Plan	1,521.00	244.20	1,538.50	3,303.70

The income from user charges of wastewater treatment in the Study Area was estimated to be around 4,149 Million Pesos over the Master Plan period, while the cost of the Wastewater Master Plan was estimated at about 3,304 Million Pesos.

The surplus of income from water supply as another income source for the Wastewater Master Plan in the Study Area could add around 634 Million Pesos over the Master Plan period if the cost of water production was assumed to be 90% of gross water supply income, and at about 317 Million Pesos over the Master Plan period when the cost of water production was assumed to be 95% of gross water supply income.

The contribution of the tour industry operators as the third income source of the Wastewater Master Plan was estimated on the basis of water consumption by tourists as percentage of total water consumption, which turned out to be around 5.3% in the Study Area (7.1% in Solidaridad), and the corresponding cumulative amount resulted in around 177 Million Pesos for the whole Study Area over the Master Plan period.

b. Financial Balance of Wastewater Master Plan

Financial balance resulting from the difference between income and cost of the Wastewater Master Plan differed depending on the Municipality in the Study Area, which was equivalent to say that the projected number of tourists differed greatly among the municipalities. The large inflow of tourists in Solidaridad Municipality made the financial balance positive not only in the Municipality, but the resulting surplus was sufficient to cover the financial deficits that were estimated to occur in Othon P. Blanco and Felipe Carrillo Puerto, thereby turning a financial surplus for the Wastewater Master Plan in the whole Study Area, as shown in the following Table.

Table 9-19: Financial Balance of Wastewater Master Plan

Unit: Million Pesos

Financial Balance	OPB	FCP	Solidaridad	Study Area
Financial Balance with Wastewater Income Only	-350.93	-113.45	1,309.36	844.97
Financial Balance with All Income Sources (WS expenses = 90% of gross income)	-139.59	-95.23	1,890.88	1,656.07
Financial Balance with All Income Sources (WS expenses = 95% of gross income)	-228.05	-104.34	1,671.30	1,389.77

The above Table shows that the financial balance was estimated to be grossly negative in Othon P. Blanco and Felipe Carrillo Puerto under the three sets of assumptions for income estimation: wastewater charges only, and all income sources including wastewater charges, income surplus of water supply (assuming costs to comprise 90% and 95% of gross income), and the share of the tour industry in the cost of Wastewater Master Plan.

c. Indices of Financial Viability of Wastewater Master Plan

The flow of income and costs of the Wastewater Master Plan over the Master Plan period was examined as regards its financial viability using the following indices: financial internal rate of return (FIRR), net present value (NPV) calculated with a 10% discount rate, and the benefit cost ratio (B/C) calculated with a 10% discount rate, as indicated in the following Table.

Table 9-20: Indices of Financial Viability of Wastewater Master Plan

Income Sources & Indices	OPB	FCP	Solidaridad	Study Area
Wastewater Income Only				
FIRR (%)	Not applicable	Not applicable	20.18	8.35
NPV10% (Million Pesos)			331.45	-84.84
B/C Ratio 10%			1.34	0.96
All Income Sources (WS expenses = 90% of gross income)				
FIRR (%)	Not applicable	Not applicable	32.76	17.12
NPV10% (Million Pesos)			644.72	343.79
B/C Ratio 10%			1.67	1.18
All Income Sources (WS expenses = 95% of gross income)				
FIRR (%)	Not applicable	Not applicable	28.66	14.62
NPV10% (Million Pesos)			537.06	220.13
B/C Ratio 10%			1.56	1.11

c.1 Financial Viability with Wastewater Treatment Service Charges

Even when the only income source was considered to be the service charges for wastewater treatment, FIRR turned out to be 20.18% in Solidaridad and 8.35% for the Study Area as a whole. On the other hand, in Othon P. Blanco and Felipe Carrillo Puerto, as the financial balance turned out to be grossly negative, the calculation of FIRR was considered to be meaningless.

As for the other indices, Solidaridad was estimated to produce NPV of 331.45 Million Pesos and a B/C ratio of 1.34, while in the Study Area as a whole NPV was estimated to be negative and the B/C ratio was estimated at 0.96 when discounted at 10%. These indices were also regarded as meaningless to compute in the case of Othon P. Blanco and Felipe Carrillo Puerto, as the financial balance turned out to be grossly negative in these two Municipalities.

c.2 Financial Viability with All Income Sources (WS expenses = 90% of gross income)

When all three income sources were included, and water supply income surplus was estimated as 10% of gross income, FIRR turned out to be 32.76% in Solidaridad and 17.12% in the Study Area. Also, NPV was estimated to be 644.72 Million Pesos in Solidaridad and 343.79 Million Pesos in the Study Area, while the B/C ratio was estimated to be 1.67 in Solidaridad and 1.18 in the Study Area, when discounted at 10%.

Even including all three income sources, the relevant financial viability indices were considered as meaningless to be calculated in Othon P. Blanco and Felipe Carrillo Puerto, as the financial balance was still negative.

c.3 Financial Viability with All Income Sources (WS expenses = 95% of gross income)

When all three income sources were included, but the expenditures on water supply were estimated to comprise 95% of gross income, then logically the financial viability indices decreased slightly. FIRR was estimated to be 28.66% in Solidaridad and 14.62% in the Study Area, while NPV was estimated to be 537.06 Million Pesos in Solidaridad and 220.13 Million Pesos in the Study Area, while the B/C ratio was estimated to be 1.56 in Solidaridad and 1.11 in the Study Area, when discounted at 10%.

Again in this case, it was considered as meaningless to calculate these financial viability indices in Othon P. Blanco and Felipe Carrillo Puerto due to the large financial deficits.

9.2.5.3 Sensitivity Analysis

Sensitivity analysis was conducted assuming the usual three cases:

Case 1: 10% decrease in income

Case 2: 10% increase in cost

Case 3: 10% decrease in income and 10% increase in cost

The income sources considered were wastewater user charges only, and all income sources with water supply income surplus considering the costs of water supply to be 90% of gross water supply income. It was considered meaningless to conduct sensitivity analysis when water supply income surplus was calculated assuming the costs of water supply to be 95% of gross water supply income, as it would be a mere repetition of the previous case and the financial viability indices would simply be lower.

Table 9-21: Sensitivity Analysis of Wastewater Master Plan

Income Sources & Indices	OPB	FCP	Solidaridad	Study Area
Base Case Wastewater Income Only FIRR (%) NPV10% (Million Pesos) B/C Ratio 10%	Not applicable	Not applicable	20.18 331.45 1.34	8.35 -84.84 0.96
Case 1: income -10% Wastewater Income Only FIRR (%) NPV10% (Million Pesos) B/C Ratio 10%	Not applicable	Not applicable	16.41 202.05 1.21	4.48 -271.96 0.86
Case 2: cost +10% Wastewater Income Only FIRR (%) NPV10% (Million Pesos) B/C Ratio 10%	Not applicable	Not applicable	16.76 235.20 1.22	4.85 -280.45 0.87
Case 3: income -10% & cost +10% Wastewater Income Only FIRR (%) NPV10% (Million Pesos) B/C Ratio 10%	Not applicable	Not applicable	13.15 105.80 1.1	0.99 -467.57 0.78
Base Case All Income Sources (WS expenses = 90% of gross income) FIRR (%) NPV10% (Million Pesos) B/C Ratio 10%	Not applicable	Not applicable	32.76 644.72 1.67	17.12 343.79 1.18
Case 1: income -10% All Income Sources (WS expenses = 90% of gross income) FIRR (%) NPV10% (Million Pesos) B/C Ratio 10%	Not applicable	Not applicable	27.19 484.00 1.54	12.42 113.80 1.06
Case 2: cost +10% All Income Sources (WS expenses = 90% of gross income) FIRR (%) NPV10% (Million Pesos) B/C Ratio 10%	Not applicable	Not applicable	28.22 558.26 1.53	12.85 148.18 1.07
Case 3: income -10% & cost +10% All Income Sources (WS expenses = 90% of gross income) FIRR (%) NPV10% (Million Pesos) B/C Ratio 10%	Not applicable	Not applicable	23.07 396.56 1.37	8.37 -81.81 0.96

In Solidaridad, the sensitivity analysis showed that the estimated income, even from wastewater service charges alone, would result in a stable financial situation, responding in similar ways to a decrease in income or an increase in cost. Even in the worst case scenario of a 10% increase in cost and a 10% reduction in income, the resulting financial viability indices were estimated as FIRR of 13.15%, NPV of 105.80 Million Pesos and B/C ratio of 1.1 when discounted at 10%. Needless to say, these indices improved notably when all income sources were considered.

For the Wastewater Master Plan in the Study Area, income from wastewater charges alone in the base case resulted in FIRR of 8.35%, which meant that the NPV was negative and the B/C ratio was below one when discounted at 10%. Under either case of a 10% decrease in income or a 10% increase in cost, the resulting FIRR was slightly lower than 5%. And the worst case of a simultaneous increase in cost and a decrease in income would result in FIRR of less than 1%.

When all income sources were considered in Wastewater Master Plan in the Study Area, the base case resulted in FIRR of 17.12%, NPV of 343.79 Million Pesos and B/C ratio of 1.18 when discounted at 10%. The case of 10% decrease in cost or a 10% increase in cost would result in FIRR of around 13%. And even the worst case of a simultaneous 10% reduction in income and a 10% increase in cost would result in FIRR of 8.37%, a negative NPV and B/C ratio of 0.96 when discounted at 10%.

9.2.5.4 Financial Plan

As the previous discussions indicated, Solidaridad and the Study Area would have sufficient income to cover the cost of the Wastewater Master Plan. On the other hand, Othon P. Blanco would need around 614 Million Pesos and Felipe Carrillo Puerto around 98 Million Pesos in additional funds in order to cover the cost of the Wastewater Master Plan in their respective Municipalities. Othon P. Blanco would need the additional funds up to 2009 while surplus is estimated between 2010 and 2015. Felipe Carrillo Puerto, on the other hand, would need these funds up to 2014.

As already mentioned, these additional funds required in OPB and FCP could be covered with the surplus estimated to occur in Solidaridad, which despite income deficits in 2004, 2005 and 2007, the surplus estimated over the Master Plan period would amount to around 1,890 Million Pesos.

Details on costs and income sources per Municipality and per year are shown in the corresponding Tables:

Othon P Blanco: Financial Plan of Wastewater Master Plan,

Felipe C Puerto: Financial Plan of Wastewater Master Plan,

Solidaridad: Financial Plan of Wastewater Master Plan, and

Study Area: Financial Plan of Wastewater Master Plan.

Table 9-22: Othon P Blanco: Financial Plan of Wastewater Master Plan

Unit: Million Pesos

Item	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Total
Costs	7.4	276.6	60.3	186.7	193.6	199.6	66.7	98.4	102.8	91.3	109.2	128.4	1,521.0
Income	8.7	276.6	60.3	186.7	193.6	199.6	137.8	160.1	173.8	184.6	198.2	215.4	1,381.4
User charges	5.5	11.9	25.1	43.5	59.7	87.3	119.8	140.2	152.3	162.0	173.8	189.0	1,170.1
Water supply	2.8	4.8	7.2	9.7	11.9	14.6	17.1	18.7	20.3	21.6	23.2	25.2	176.9
Tour industry	0.4	13.6	2.0	4.6	3.8	3.3	0.9	1.3	1.2	1.0	1.1	1.2	34.4
Other sources	0.0	246.4	26.0	129.0	118.1	94.5	0.0	0.0	0.0	0.0	0.0	0.0	614.0
Balance	1.3	0.0	0.0	0.0	0.0	0.0	71.1	61.7	71.0	93.3	89.0	87.0	474.5

Table 9-23: Felipe C Puerto: Financial Plan of Wastewater Master Plan

Unit: Million Pesos

Item	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Total
Costs	2.0	17.5	3.3	3.7	17.5	4.5	23.5	43.4	30.5	31.4	32.9	34.0	244.2
Income	2.0	17.5	3.3	3.7	17.5	4.5	23.5	43.4	30.5	31.4	32.9	36.7	149.0
User charges	0.1	0.4	0.9	1.7	2.5	3.7	8.5	13.0	18.1	22.5	26.9	32.4	130.7
Water supply	0.0	0.2	0.3	0.4	0.5	0.6	1.2	1.7	2.4	3.0	3.6	4.3	18.2
Tour industry	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other sources	1.9	17.0	2.1	1.6	14.5	0.2	13.7	28.7	10.0	5.9	2.4	0.0	98.0
Balance	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.7	2.9

Table 9-24: Solidaridad: Financial Plan of Wastewater Master Plan

Unit: Million Pesos

Item	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Total
Costs	165.7	186.5	56.7	338.5	62.7	209.5	199.5	64.7	62.2	64.4	69.2	58.9	1,538.5
Income	62.9	78.5	96.8	170.4	186.6	262.7	343.9	386.0	416.1	443.2	473.8	508.5	3,429.4
User charges	23.7	37.5	70.4	113.9	151.3	212.1	289.7	337.0	363.9	387.8	414.7	445.9	2,847.9
Water supply	11.9	15.0	20.1	25.3	30.3	35.4	41.4	44.9	48.5	51.7	55.3	59.5	439.2
Tour industry	27.3	26.0	6.3	31.3	5.1	15.2	12.9	4.0	3.7	3.7	3.8	3.1	142.4
Other sources	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Balance	-102.8	-108.0	40.1	-168.1	123.9	53.2	144.4	321.3	353.9	378.8	404.6	449.6	1,890.9

Table 9-25: Study Area: Financial Plan of Wastewater Master Plan

Unit: Million Pesos

Item	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Total
Costs	175.1	480.6	120.3	528.9	273.8	413.6	289.7	206.5	195.5	187.1	211.3	221.3	3,303.7
Income	73.6	372.6	160.4	360.9	397.7	466.8	505.2	589.5	620.3	659.3	704.9	760.6	4,959.8
User charges	29.3	49.7	96.5	159.1	213.5	303.1	418.0	490.2	534.2	572.4	615.4	667.3	4,148.7
Water supply	14.7	19.9	27.6	35.4	42.7	50.5	59.7	65.4	71.2	76.3	82.1	89.0	634.3
Tour industry	27.7	39.6	8.2	35.8	8.9	18.5	13.8	5.3	4.9	4.7	5.0	4.4	176.8
Other sources	1.9	263.4	28.1	130.6	132.6	94.7	13.7	28.7	10.0	5.9	2.4	0.0	712.0
Balance	-101.5	-108.0	40.1	-168.0	123.9	53.2	215.5	383.0	424.8	472.2	493.6	539.3	2,368.1

9.2.6 Implementation Plan

Order of implementation of works should be decided with taking into account cost-effectiveness. Table 9-26 shows cost per ton of BOD removal amount. According to the table, it is found that the implementation of the works in Solidaridad is the most cost-effective, subsequently, Othon P Blanco and Felipe C Puerto, from the aspect of treatment level, Level 4 is the most cost-effective, subsequently, Level 3, Level 2 and Level 1. Table 9-27, Table 9-28, Table 9-29 and Table 9-30 shows achievement ratio of the works in respective municipalities and in treatment levels that are set based on the order of cost-effectiveness.

Table 9-26: Unit Investment Cost of BOD Remove (2004 to 2015)

Level	Total investment (million pesos)	BOD remove al amount (ton)	BOD removal unit investment cost(pesos/ton)
OTHON P. BLANCO			
Level 1	166.513	1,960.8	84,921
Level 2	211.62	4,996.0	42,358
Level 3	192.546	6,752.6	28,514
Level 4	604.328	37,119.5	16,281
Total	1,175.007	50,828.9	23,117
FELIPE CARRILLO PUERTO			
Level 1	100.668	1,056.0	95,330
Level 2	31.622	1,115.3	28,353
Level 3	67.843	2,323.6	29,197
Total	200.133	4,494.9	44,524
SOLIDARIDAD			
Level 1	36.994	482.4	76,687
Level 2	11.186	705.5	15,855
Level 3	200.093	8,015.6	24,963
Level 4	894.393	56,121.2	15,937
Total	1,142.666	65,324.7	17,492

Table 9-27: Achievement Ratio in the Whole Study Area

	Target treatment amount (m3/day)					Achievement Ratio				
Year	Level 1	Level 2	Level 3	Level 4	Total	Level 1	Level 2	Level 3	Level 4	Total
2003	91.0	472.3	115.7	27,934.1	28,613.1	0.6%	2.7%	0.4%	26.9%	17.5%
2004	94.3	524.2	115.7	27,934.1	28,668.3	0.6%	2.9%	0.4%	26.9%	17.6%
2005	97.7	575.3	432.0	36,279.4	37,384.4	0.6%	3.2%	1.6%	34.9%	22.9%
2006	341.5	1,273.1	4,055.0	46,216.9	51,886.5	2.2%	7.1%	15.5%	44.5%	31.8%
2007	576.4	2,152.7	7,678.0	56,154.4	66,561.5	3.8%	12.1%	29.3%	54.0%	40.8%
2008	805.4	2,381.0	11,301.0	66,091.9	80,579.3	5.3%	13.4%	43.1%	63.6%	49.4%
2009	1,030.1	3,598.8	14,924.0	75,489.9	95,042.8	6.8%	20.2%	56.9%	72.6%	58.2%
2010	2,945.2	4,743.7	18,546.6	85,966.7	112,202.2	19.4%	26.6%	70.7%	82.7%	68.8%
2011	5,590.4	6,971.7	20,080.4	89,558.8	122,201.3	36.7%	39.1%	76.6%	86.2%	74.9%
2012	7,603.1	9,930.2	21,614.2	93,150.9	132,298.4	50.0%	55.8%	82.4%	89.6%	81.1%
2013	9,736.8	11,637.8	23,148.0	96,743.0	141,265.6	64.0%	65.4%	88.3%	93.1%	86.6%
2014	12,021.0	14,323.0	24,681.8	100,335.1	151,360.9	79.0%	80.4%	94.1%	96.5%	92.8%
2015	15,220.1	17,807.9	26,215.8	103,927.7	163,171.5	100.0%	100.0%	100.0%	100.0%	100.0%

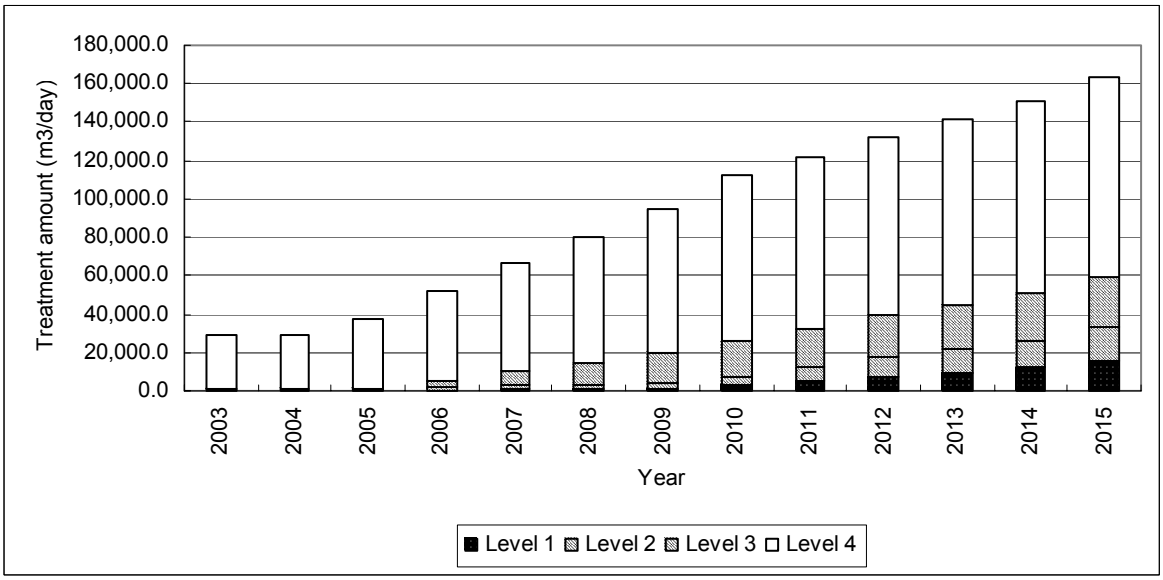


Figure 9-2: Target treatment Amount in Whole Study Area

Table 9-28: Achievement Ratio in Othón P. Blanco

	Target treatment amount (m3/day)					Achievement Ratio				
Year	Level 1	Level 2	Level 3	Level 4	Total	Level 1	Level 2	Level 3	Level 4	Total
2003	0	314.7	0	7,273	7,587	0.0%	2.5%	0.0%	17.6%	10.5%
2004	0	327.7	0	7,273	7,600	0.0%	2.6%	0.0%	17.6%	10.5%
2005	0	340.5	0	12,737	13,078	0.0%	2.7%	0.0%	30.8%	18.1%
2006	240.6	1,003.0	1504.9	17,380	20,129	2.9%	8.1%	14.7%	42.0%	27.8%
2007	472.4	1,845.6	3009.8	22,023	27,351	5.7%	14.9%	29.5%	53.2%	37.8%
2008	698.3	2,037.1	4514.7	26,666	33,916	8.4%	16.4%	44.2%	64.4%	46.9%
2009	919.9	3,221.0	6019.6	31,309	41,470	11.1%	26.0%	58.9%	75.6%	57.3%
2010	1,999.3	3,435.1	7524.4	35,953	48,911	24.1%	27.7%	73.7%	86.8%	67.6%
2011	3,195.3	5,180.8	8062.5	37,044	53,483	38.6%	41.7%	78.9%	89.5%	74.0%
2012	4,182.9	7,226.4	8600.6	38,135	58,145	50.5%	58.2%	84.2%	92.1%	80.4%
2013	5,156.3	8,393.4	9138.7	39,227	61,915	62.2%	67.6%	89.5%	94.7%	85.6%
2014	6,265.5	10,220.1	9676.8	40,318	66,481	75.6%	82.3%	94.7%	97.4%	91.9%
2015	8,284.5	12,410.6	10214.9	41,410	72,320	100.0%	100.0%	100.0%	100.0%	100.0%

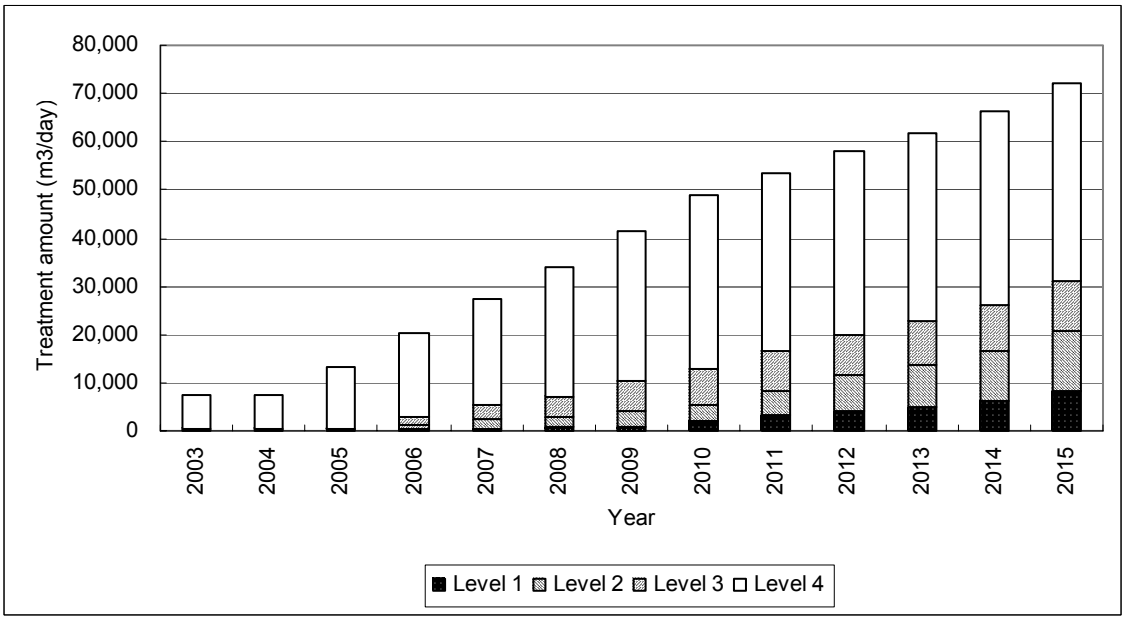


Figure 9-3: Target treatment Amount in Othón P. Blanco

Table 9-29: Achievement Ratio in Felipe Carrillo Puerto

	Target treatment amount (m3/day)				Achievement Ratio			
Year	Level 1	Level 2	Level 3	Total	Level 1	Level 2	Level 3	Total
2003	0.0	0.0	115.7	115.7	0.0%	0.0%	3.0%	0.9%
2004	0.0	0.0	115.7	115.7	0.0%	0.0%	3.0%	0.9%
2005	0.0	0.0	432.0	432.0	0.0%	0.0%	11.3%	3.4%
2006	0.0	0.0	770.6	770.6	0.0%	0.0%	20.2%	6.1%
2007	0.0	0.0	1,109.2	1,109.2	0.0%	0.0%	29.1%	8.9%
2008	0.0	0.0	1,447.8	1,447.8	0.0%	0.0%	37.9%	11.6%
2009	0.0	0.0	1,786.4	1,786.4	0.0%	0.0%	46.8%	14.3%
2010	514.7	894.4	2,125.0	3,534.1	10.4%	23.9%	55.7%	28.2%
2011	1,646.6	902.7	2,463.6	5,012.9	33.2%	24.1%	64.5%	40.0%
2012	2,386.5	1,790.9	2,802.2	6,979.6	48.1%	47.8%	73.4%	55.7%
2013	3,255.2	2,306.9	3,140.8	8,702.9	65.6%	61.6%	82.3%	69.5%
2014	4,151.0	2,778.3	3,479.4	10,408.7	83.6%	74.1%	91.1%	83.1%
2015	4,964.4	3,747.9	3,817.9	12,530.2	100.0%	100.0%	100.0%	100.0%

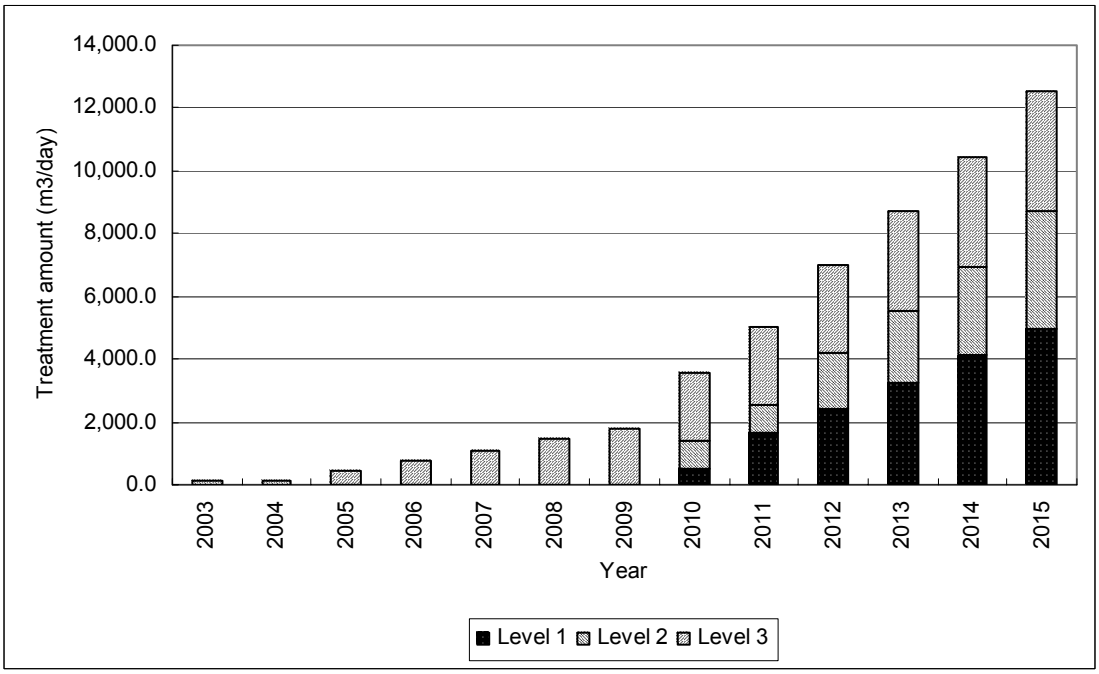


Figure 9-4: Target treatment Amount in Felipe Carrillo Puerto

Table 9-30: Achievement Ratio in Solidaridad

	Target treatment amount (m3/day)					Achievement Ratio				
Year	Level 1	Level 2	Level 3	Level 4	Total	Level 1	Level 2	Level 3	Level 4	Total
2003	91.0	157.6	0.0	20,661.5	20,910.1	4.6%	9.6%	0.0%	33.0%	26.7%
2004	94.3	196.5	0.0	20,661.5	20,952.3	4.8%	11.9%	0.0%	33.0%	26.8%
2005	97.7	234.8	0.0	23,542.4	23,874.9	5.0%	14.2%	0.0%	37.7%	30.5%
2006	100.9	270.1	1,779.5	28,836.8	30,987.3	5.1%	16.4%	14.6%	46.1%	39.6%
2007	104.0	307.1	3,559.0	34,131.2	38,101.3	5.3%	18.6%	29.2%	54.6%	48.6%
2008	107.1	343.9	5,338.5	39,425.6	45,215.1	5.4%	20.9%	43.8%	63.1%	57.7%
2009	110.2	377.8	7,118.0	44,180.5	51,786.5	5.6%	22.9%	58.4%	70.7%	66.1%
2010	431.2	414.2	8,897.2	50,014.2	59,756.8	21.9%	25.1%	73.0%	80.0%	76.3%
2011	748.5	888.2	9,554.3	52,514.9	63,705.9	38.0%	53.8%	78.4%	84.0%	81.3%
2012	1,033.7	912.9	10,211.4	55,015.6	67,173.6	52.4%	55.3%	83.8%	88.0%	85.8%
2013	1,325.3	937.5	10,868.5	57,516.3	70,647.6	67.2%	56.8%	89.2%	92.0%	90.2%
2014	1,604.5	1,324.6	11,525.6	60,017.0	74,471.7	81.4%	80.3%	94.6%	96.0%	95.1%
2015	1,971.2	1,649.4	12,183.0	62,517.8	78,321.4	100.0%	100.0%	100.0%	100.0%	100.0%

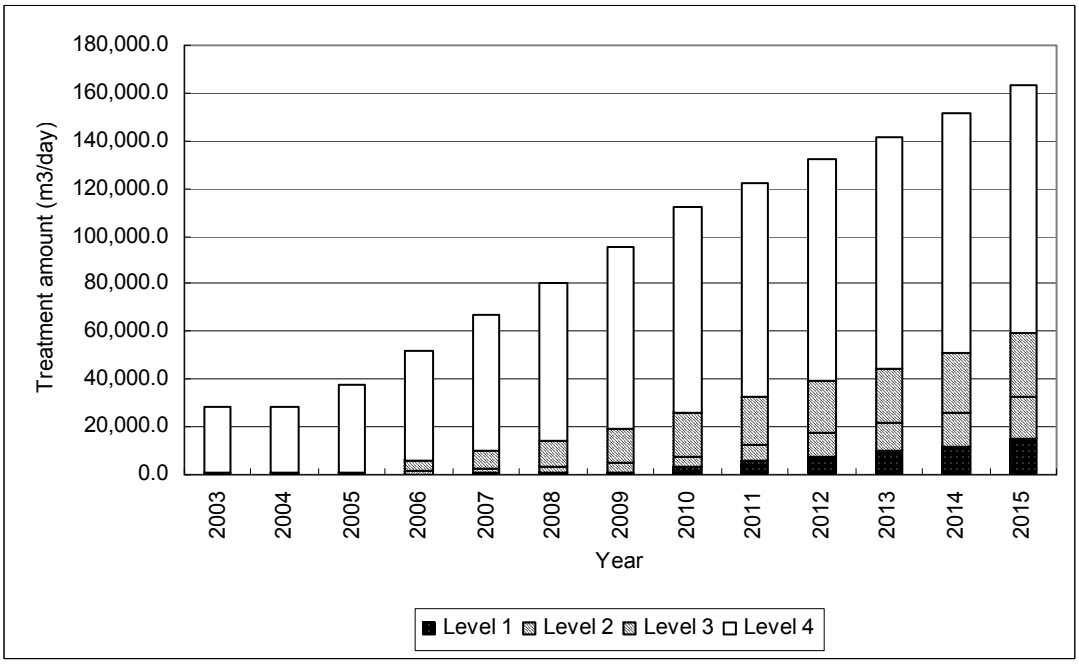


Figure 9-5: Target treatment Amount in Solidaridad

9.3 Solid Waste Management Master Plan

9.3.1 Objectives, Targeted Values and Target Years

a. Principal Objectives and Targeted Values

The principal objective of the Solid Waste Management (SWM) Master Plan is;

To preserve the groundwater and the coastal aquatic environment in the study area

Targeted value is;

BOD discharge amount originated from solid waste is to be less than 2,100 ton/year by 2015.

b. Particular Objectives and Targeted Values

The master plan aims at achieving the principal objective, in addition, at accomplishing the following particular objectives inherent to solid waste management.

- ***Provision of sanitary living environment:*** by removing waste from houses and communities (waste collection)
- ***Mitigation of environmental impact cased by waste:*** by properly disposing of collected waste (proper disposal)
- ***Resource conservation:*** by contributing to establishment of a recycling-oriented society through source reduction and recycling, etc. (waste minimization)

The table below shows targeted values of the particular objectives by the municipalities.

Table 9-31: Target Values of the SWM Master Plan (by Municipalities)

Items	*Present (2003)*	*Particular Goals in 2015*
Waste minimization rate	*0*	*Study Area: 23%* *OPB: 23%* *FCP: 15%* *SOL: 24%*
Collection rate *( ): inc. rural area*	*Study area: 75% (61%)* *OPB: 72% (57%)* *FCP: 29% (18%)* *SOL: 88% (82%)*	*Study area: 99% (86%)* *OPB: 99% (82%)* *FCP: 87% (49%)* *SOL:100% (95%)*
Disposal level	*OPB: open and controlled dump* *FCP: open dump* *SOL: open and landfill with gas control*	*Population — Disposal level* *2,500 - 7,999: controlled dump* *8,000 - 34,999: enclosed dump* *34,999 - 99,999: landfill with gas control* *100,000 and more: landfill with leachate control*

OPB, Othon P Blanco; FCP, Felipe C Puerto, SOL, Solidaridad

Targeted values are also set by the urban groups. Table 9-32 shows the urban groups and communities belonging to them. Table 9-33 shows target values set for the respective urban groups. Table 9-34 shows components of waste minimization.

Table 9-32: Urban Groups

Urban G	Municipality	Community
1	OPB	CALDERITAS, CHETUMAL, XUL-HA
2	OPB	ALVARO OBREGON, INGENIO ALVARO OBREGON, SERGIO BUTRON CASAS
3	OPB	NICOLAS BRAVO
4	OPB	BACALAR, LIMONES, MAYA BALAM
5	OPB	MAHAHUAL, PUNTA PULTICUB, XAHUACHOL, XCALAK
6	FCP	FELIPE CARRILLO PUERTO, SENOR
7	FCP	CHUNHUHUB
8	FCP	TEPICH, TIHOSUCO
9	SOL	CIUDAD CHEMUYIL, NUEVO AKUMAL, PLAYA DEL CARMEN, TULUM
10	SOL	COBA

Table 9-33: Target Values of the SWM Master Plan (by Urban Group)

Urban Group	Population		Waste Minimization		Collection Rate		Disposal Level	
	2003	2015	2003	2015	2003	2015	2003	2015
1	137,355	172,488	0%	25%	90%	100%	Controlled dump	Landfill with leachate control
2	9,558	12,474	0%	15%	0%	90%	Open dump	Enclosed dump
3	3,893	4,854	0%	15%	0%	80%	Open dump	Controlled dump
4	19,106	43,418	0%	15%	0%	95%	Open dump	Landfill with gas control
5	626	108,215	0%	25%	0%	100%	Open dump	Landfill with leachate control
6	21,784	25,009	0%	15%	44%	90%	Open dump	Enclosed dump
7	4,582	5,410	0%	15%	0%	80%	Open dump	Controlled dump
8	6,659	7,854	0%	15%	0%	80%	Open dump	Controlled dump
9	128,061	379,664	0%	25%	89%	100%	Landfill with gas control	Landfill with leachate control
10	1,704	3,000	0%	15%	0%	80%	Open dump	Controlled dump
Total	333,328	762,386	-	-	-	-	-	-

Table 9-34: Waste Minimization Rate of the SWM Master Plan

Urban Group	*Population*	*Minimization rate*		*Methods*
	2015	*Source reduction*	*Composting*	
1	*172,488*	*15%*	*10%*	*Environmental education, backyard composting, pruning waste composting*
2	*12,474*	*15%*	*0%*	*Environmental education, backyard composting*
3	*4,854*	*15%*	*0%*	*Environmental education, backyard composting*
4	*43,418*	*15%*	*0%*	*Environmental education, backyard composting*
5	*108,215*	*15%*	*10%*	*Environmental education, backyard composting, pruning waste composting*
6	*25,009*	*15%*	*0%*	*Environmental education, backyard composting*
7	*5,410*	*15%*	*0%*	*Environmental education, backyard composting*
8	*7,854*	*15%*	*0%*	*Environmental education, backyard composting*
9	*379,664*	*15%*	*10%*	*Environmental education, backyard composting*
10	*3,000*	*15%*	*0%*	*Environmental education, backyard composting, pruning waste composting*
Total	*762,386*	*-*	*-*	*-*

c. Target Year

The target year for the master plan is set up as follows:

Master Plan: Year 2015

Strategic actions to achieve the objectives should be, in practice, introduced step by step approach towards the target year 2015. It is recommended to divide the period up to the target year into three phases as follows.

Phase 1:	***Short term improvement***	***(2004 to 2007)***
Phase 2:	***Medium term improvement***	***(2008 to 2011)***
Phase 3:	***Long term improvement***	***(2012 to 2015)***

9.3.2 Strategies

The following eight points are strategies to accomplish the objectives.

1. ***Focusing on the urban area***
2. ***Development of SWM systems accommodating to various size of communities***
3. ***Introduction and promotion of waste minimization***
4. ***Financial self-sufficiency***
5. ***Cooperation among the three government levels***
6. ***Development of legal system***
7. ***Strengthening of executing bodies of SWM***
8. ***Establishment of a new SWM system in Costa Maya***

1. Focusing on the urban area

Although hundreds of communities are dispersed over the study area, most of population centers in some communities. Only 24 urban communities have 2,500 and over persons, which are estimated to have 85% of total population in the target year of 2015.

Meanwhile, life in rural villages discharges small amount of waste and there are spaces to dispose of them. Therefore, demand for solid waste service is not so strong.

Consequently, the Master Plan of SWM focuses on the urban area taking into account the demand and cost-effectiveness.

2. Development of SWM systems accommodating to various size of communities

Even urban communities, population size of them are various. It is inappropriate to adopt the same SWM system to all communities having different population sizes. That is, communities with small population cannot afford and do not require 100% collection rate and sophisticated sanitary landfill.

Therefore, various type of SWM systems shall be prepared and employed corresponding to population size of communities.

3. Introduction and promotion of waste minimization

Waste amount generated per person in the study area is not so different from it in developed countries. Meanwhile, the new federal law, “Ley General para la Prevencion y Gestion Integral de los Residuos,” takes up waste minimization as an important policy. With taking

into account these issues, waste minimization shall be introduced and promoted in the study area.

4. Financial self-sufficiency

Most of SWM costs of the three municipalities are not covered with specific user charges of the SWM service, but with general funds of the municipal budget, which consist mostly of subsidies from the state and/or federal governments. Then, there is a risk that the SWM may fall into disarray if the state or the federal government changes their funding policy of municipal budgets, despite recognizing that the SWM is one of the responsibilities inherent to the municipal government. When SWM in a municipality is paid for by general funds, the likely outcome is low awareness to provide the service on the basis of careful considerations of the cost and income specific to the service. Then, SWM operated with general funds may result in careless cost management, inefficient works and low service quality, and the low awareness on SWM costs and income held by municipal authorities may spread to the general citizenry. In order to improve the said possible difficulties mentioned above, achieving financial self- sufficiency will be the goal of the financial plan.

5. Cooperation among the three government levels

Requirements for SWM is recently getting various and sophisticated such as sanitary landfilling, waste minimization, public-private partnership, hazardous waste management, etc. It will compound further in the future. Then, it is impossible for municipalities by themselves to cope with them. Therefore, a framework, where the three governments, the federal, the state and the municipal governments, are able to cooperate, shall be formulated.

6. Development of legal system

There are many actors in SWM, such as governments who are service providers or supervisors, citizens and business entities who are waste dischargers, the private sector who participates in service provision, and non government organizations who may be bridge builder between the governments and the citizens. In order them to appropriately participate in SWM, legal system shall be developed.

7. Strengthening of executing bodies of SWM

Executing bodies of SWM are required to develop their capacity in order to cope with new issues such as sanitary landfilling, waste minimization and rapid urbanization by tourism development. All of other strategies strengthen their capacity. However, those should not be carried out individually. Those should be integrated. Experiences and knowledge should be

accumulated in the executing bodies. Otherwise, they are not able to continuously develop their capacity in the future.

8. Establishment of a new SWM system in Costa Maya

In Costa Maya, various infrastructures for tourism development have been built such as roads, electricity, and a pier for liners. And, number of tourists has been increased. However, public services have not yet been developed in the area. Solid waste service is carried out in small scale by some village people. As such system will not be able to cope with future development, SWM system shall be established to protect the beautiful nature in the area.

9.3.3 Proposed Measures

9.3.3.1 Description of Proposed Measures

This section describes proposed measures to accomplish the objectives. The table below summarizes the proposed measures, and each of them is subsequently explained.

Table 9-35: Strategies and Proposed Measures

Strategies	*Proposed Measures*
1. Focusing on the urban area	*11. Focusing on the urban area*
2. SWM systems accommodating to various size of communities	*21. Flexible arrangement of collection rate* *22. Flexible arrangement of final disposal manners*
3. Introduction and promotion of waste minimization	*31. Environmental education on waste minimization* *311. Environmental education and recycling activities in schools* *312. Environmental education and recycling activities in communities* *313. Advertisement of importance of waste minimization through public institutions and/or mass media* *32. Promotion of backyard composting* *321 Preparing and distributing materials how to make compost from garden waste* *322. Establishing visit instruction system of composting* *333. Demonstrating composting in public institutions* *33. Pruning waste composting* *34. Setting of Waste Minimization Rate*
4. Financial self-sufficiency	*41. Income improvement* *411. General application of service charges* *412. Realistic service charges* *413. Timely billing and payment facility* *414. Control of bill collection* *415. Specific use of income* *42. Cost reduction* *421. Improvement of waste collection works* *422. Constant monitoring*
5. Cooperation among the three government levels	*51. Establishment an information system for the integral management*
6. Development of legal system	*61. Formulation of a municipal regulation on SWM* *62. Formulation of rules for public-private partnership*
7. Strengthening of executing bodies of SWM	*71. Establishment of a specialized administrative unit in SEDUMA* *72. Restructuring of municipal executing bodies of SWM*
8. Establishment of a new SWM system in Costa Maya	*81. Establishment of an organizational and institutional framework* *82. Introduction of culture of waste minimization* *83. Preparation of establishing a firm SWM system*

1. Focusing on the urban area

11. Focusing on the urban area

Ten urban groups consisting of 24 urban communities in the table below are basically subject to the Master Plan.

Table 9-36: Urban Communities subject to the Master Plan

Urban G	Municipality	Community	Population	
			2003	2015
1	OPB	CALDERITAS, CHETUMAL, XUL-HA	137,355	172,488
2	OPB	ALVARO OBREGON, INGENIO ALVARO OBREGON, SERGIO BUTRON CASAS	9,558	12,474
3	OPB	NICOLAS BRAVO	3,893	4,854
4	OPB	BACALAR, LIMONES, MAYA BALAM	19,106	43,418
5	OPB	MAHAHUAL, PUNTA PULTICUB, XAHUACHOL, XCALAK	626	108,215
6	FCP	FELIPE CARRILLO PUERTO, SENOR	21,784	25,009
7	FCP	CHUNHUHUB	4,582	5,410
8	FCP	TEPICH, TIHOSUCO	6,659	7,854
9	SOL	CIUDAD CHEMUYIL, NUEVO AKUMAL, PLAYA DEL CARMEN, TULUM	128,061	379,664
10	SOL	COBA	1,704	3,000
Urban sub-total			333,328	762,386
Rural			101,637	130,408
Total			434,965	892,794
Urban/Total			76.6%	85.4%

2. SWM systems accommodating to various size of communities

21. Flexible arrangement of collection rate

Collection rate of waste shall be flexibly arranged corresponding to community size with taking into account not to deteriorate its living environment and to heighten cost-effectiveness of the service, as shown in the following table.

Table 9-37: Collection rates adopted in the Master Plan

Population (nos.)	Collection Rate
1 – 2,499	0%
2,500 - 7,999	80%
8,000 - 34,999	90%
34,999 - 99,999	95%
100,000 -	100%

22. Flexible arrangement of final disposal manners

Final disposal manners shall be flexibly arranged corresponding to community size with taking into account not to deteriorate the environment where waste is disposed of and to heighten cost-effectiveness of operation of final disposal. Four manners of final disposal are proposed as shown in Table 9-38, which can be developed in phase corresponding to growth of community. It should be mentioned that the manners 1, 2 and 3 are improvement of existing dump sites, meanwhile the manner 4 is construction of a new sanitary landfill which shall comply with correspondence Mexican norms.

Table 9-38: Final Disposal Manners adopted in the Master Plan

Disposal manners	*Contents*
1:Controlled dump (population: less than 8,000)	• *Inspection on incoming waste: to measure disposal amount, to control hazardous waste, etc.* • *Approach road, on-site road: to secure access to a dumping area* • *Landfill equipment: to accumulate waste*
2:Enclosed dump (population: 8,000 - 34,999)	• *Fence: to prohibit for unauthorized persons to enter the site* • *Dike: to avoid waste to be scattered, to prevent water from coming in* • *Buffer: to keep enough space to adjacent property* • *Drainage: surrounding and on-site drains*
3:Landfill with gas control (population: 34,999 - 99,999)	• *Soil cover: to prohibit vector proliferation, to prevent fire and mal odor, to minimize rainwater infiltration, to improve aesthetics* • *Gas removal facility: to prevent fire and explosion, to encourage waste decomposition* • *Weighbridge: important for SWM*
4:Landfill with leachate control (population: 100,000 and over)	• *Bottom liner: to prevent leachate to infiltrate into ground (groundwater contamination)* • *Leachate collection facility: to collect and discharge leachate to the outside* • *Leachate treatment facility: to treat leachate to a certain quality that does not give serious environment impact*

3. Introduction and promotion of waste minimization

31. Environmental education on waste minimization

Importance of resource conservation and manners of waste minimization shall be disseminated through environmental education and recycling activities. The following are proposed measures.

311. Environmental education and recycling activities in schools
312. Environmental education and recycling activities in communities
313. Advertisement of importance of waste minimization through public institutions and/or mass media

32. Promotion of backyard composting

Waste component in the Study Area is accentuated in a large portion of garden waste that could be disposed of in houses by composting. Waste discharged from houses could be reduced by composting and the citizens could be encouraged in waste minimization and resource conservation through such concrete actions. The following measures are proposed for that purpose.

321 Preparing and distributing materials how to make compost from garden waste
322. Establishing visit instruction system of composting
333. Demonstrating composting in public institutions

It is expected to minimize 15% of waste generation amount at source by the environmental education and the backyard composting.

33. Pruning waste composting

A large amount of pruning waste from roadside trees is generated. Also, pruning waste that does not suit to backyard composting is discharged a lot from households. Those shall be subject to composting, not to landfilling. The amount will be 10% of total generation amount of waste.

4. Financial self-sufficiency

Income improvement and cost reduction are crucial for accomplishing financial self-sufficiency in SWM. For this purpose, it is important to secure fairness based on beneficiaries paying a fair price for the quality of service they receive, to attain improvement of service quality, to pursue transparency in accounting, and to achieve civil minimum or provision of minimum sanitary living environment. The measures that may be applied to achieve financial self-sufficiency through income improvement and cost reduction are the following.

4.1 Income improvement

4.1.1 General application of service charges

The application of service charges differs greatly in the three municipalities comprising the Study Area. Solidaridad applies service charges on households and business firms, while OPB applies the service charges only on business firms, and FCP applies no service charges. OPB and Solidaridad set their own service charges every year.

From the financial viewpoint, all users of solid waste service should pay service charges, because the solid waste service entails costs, and users of the service generally accept to pay at least partially the cost of the service. Households are important generators of solid waste,

and therefore should actively participate in this cost recovery effort by paying their share of service costs. According to the proposed regulation on solid waste management, households are expected to pay fixed monthly charges, while commercial-industrial firms and institutions are expected to pay volume-based tariff as a way to introduce fairness by applying the polluter-pays-principle.

The general application of service charges seeks mainly to increase income from the SW service by incorporating households and business firms as groups of paying customers, in order to include all generators of solid waste.

4.1.2 Realistic service charges

The practice of OPB and Solidaridad to set service charges on yearly basis eliminates a troublesome rigidity in financial management. This rigidity refers to the all too common difficulty in updating service charges in response to changing service costs. Service charges should seek to recover the service costs as much as possible. However, increasing SW service charges as a means to improve income should be the last resort, rather using other measures such as updating and expanding the customer base and improving the bill collection efficiency.

The customer base of service users should be updated and expanded on a permanent basis. Double checking with other data sources will increase accuracy. Also, a better knowledge of types of service users will permit the design and implementation of measures to provide improved service tailored to the needs of diverse customer groups. This can increase the number of satisfied service users and their willingness to pay for the service.

4.1.3 Timely billing and payment facility

Billing periodicity set in the proposed regulation on solid waste management should be strictly respected, bimonthly for households, and monthly for commercial and industrial firms, as well as for institutional clients. SW service users should be given the facility to make payments not only in the main offices of each municipality, but also in places where people frequently go to, like supermarkets, as is the case with payments of any other public utilities. Every effort should be made to ensure that payments are collected in officially authorized places, and not in unofficial ways like by unauthorized drivers of SW collection trucks. In other words, payments made by the users of SW service should reach the municipal coffers instead of being diverted to private uses.

4.1.4 Control of bill collection

Bill collection should be carefully conducted in order to keep late accounts under control. This implies a clarification on the reasons why payment of a service user becomes late, and the application of fines and penalties when payments by service users are not done in a timely fashion. The period of two months after due date to initiate collection procedures should be strictly enforced, in addition to the application of fines and penalties when deemed necessary.

Bill collection should be monitored every billing period in order to increase collection efficiency (collection as percentage of billing), and to minimize the number of service users that run more than two months late in paying their bills. Even if bill collection efficiency is satisfactory, the non-paying group should be systematically monitored to get a better idea on late accounts, or the number of weeks or months during which payments are late. The data on types of service users who do not pay may permit taking appropriate actions such as information/education campaigns, imposing fines and/or penalties. The idea of automatically attaching the monetary value of late accounts on the property tax of the following year may prove to be effective.

4.1.5 Specific use of income

The income obtained as solid waste service charges should ideally be earmarked for use in the improvement of the service. The strict implementation of this recommendation may cause financial difficulties during the initial stage, if it implies that general funds can not be depended upon to finance SW service. Therefore, an exception should probably be made for the initial few years, during which a mix of general funds and service charges should be used in the SWM. Meanwhile, proper procedures should be introduced in the existing system so as to improve bill collection and earmark the service charges. Then, the Municipal Service Department can move toward operating autonomy, and can have the satisfaction of playing an active role in service improvement, actually seeing the service becoming increasingly more efficient.

4.2 Cost reduction

4.2.1 Improvement of waste collection works

As solid waste collection works usually comprise a large portion of total SWM costs (42% in OPB in 2002), reduction of solid waste collection cost can have a large impact on the reduction of the overall SWM cost. The re-design of solid waste collection routes and other improvements can induce a less wasteful use of time and resources, thereby contributing to a more efficient operation of the solid waste collection service at a lower cost.

4.2.2 Constant monitoring

Financial performance should be constantly monitored through selected quantified indicators, so as to promptly introduce improvement measures where and when the monitored indicators turn away from the acceptable range of values.

Performance indicators will serve to monitor such summary aspects as the cost per ton of solid waste collection, the cost of street sweeping, the cost of final disposal, and the cost per ton of the overall cost of solid waste management. Careful monitoring of periodic evolution of these indicators will permit taking timely corrective actions. An important indicator will be bill collection efficiency, or the ratio between the monetary amount of collection and the monetary amount of billing.

5. Cooperation among the three government levels

51. Establishment an information system for the integral management

The new law requires the creation of the Information System for the Integral Management of Wastes with the purpose to build a coordination and information methodology between three levels of government in issues related to prevention of generation, valorization, and integral management of wastes.

The Information System for the Integral Solid Waste Management (SIGIR) has been established. This system constitutes a mechanism of coordination and information among the three government levels on regards of prevention of the generation, valorization and integral management of solid waste.

Initially SEMARNAT (Quintana Roo Branch), SEDUMA and the municipalities of Othon P. Blanco, Felipe Carrillo Puerto and Solidaridad are part of SIGIR. Additionally, SIGIR will be used in order to track the implementation of the Master Plan.

It is recommended to incorporate other governmental, academic and community organizations as well as the private sector, whose activities are related to the management of solid waste and environmental protection in general.

SIGIR may be the ideal instrument for starting the organization of the Executive Unit of the Master Plan. SEDUMA is suggested as the coordinating organ for this Executive Unit.

JICA should consider an electronic connection with SIGIR and the possible Executive Unit, with the purpose of giving continuity and assistance to the implementation of the Master Plan during the period of implementation.

6. Development of legal system

61. Formulation of a municipal regulation on SWM

The draft of the "Regulation for the Rendering of the Public Service for the Integral Management of Urban Solid Waste" is being considered for its approval by the municipalities of Othon P. Blanco, Felipe Carrillo Puerto and Solidaridad.

It is expected on the short term to have an instrument that allows regulating the relationship between the municipality, the clients and the private sector on regards of the integral management of solid waste in order to preserve and recuperate the quality of the environment and the protection to public health.

The "General Law for the Prevention and Integral Management of Waste" has not had enough diffusion by part of the competent organizations. Using SIGIR should start a process of public information and coordination among the several organizations involved and to execute what has been stated in the General Law.

62. Formulation of rules for public-private partnership

The experience achieved with the participation of the private sector (PPS) on SWM has not been successful. The municipality of Solidaridad has finished the contract with the private sector. In the neighboring municipality of Benito Juarez a very difficult situation is being generated concerning the final Disposal of SW and the debts that are maintained with the contractor.

Before the PPS the municipalities should define, together with the community, about the quality of the service that will be rendered, the costs estimated, the level of the fees and the intention and willingness of payment of the population.

Because this service is considered as a public asset, it is precise that the population pays for the rights of the rendering of the service, this payment should be universal to all inhabitants and the society should subsidize the families that can not make the payment.

The Master Plan establishes the bases that should be considered in the rendering of the service and this is a guide that defines the participation of the private sector.

The legal procedures for the PPS are known by the competent authorities; the PPS on the SWM in Mexico has had successful examples in several cities.

7. Strengthening of executing bodies of SWM

71. Establishment of a specialized administrative unit in SEDUMA

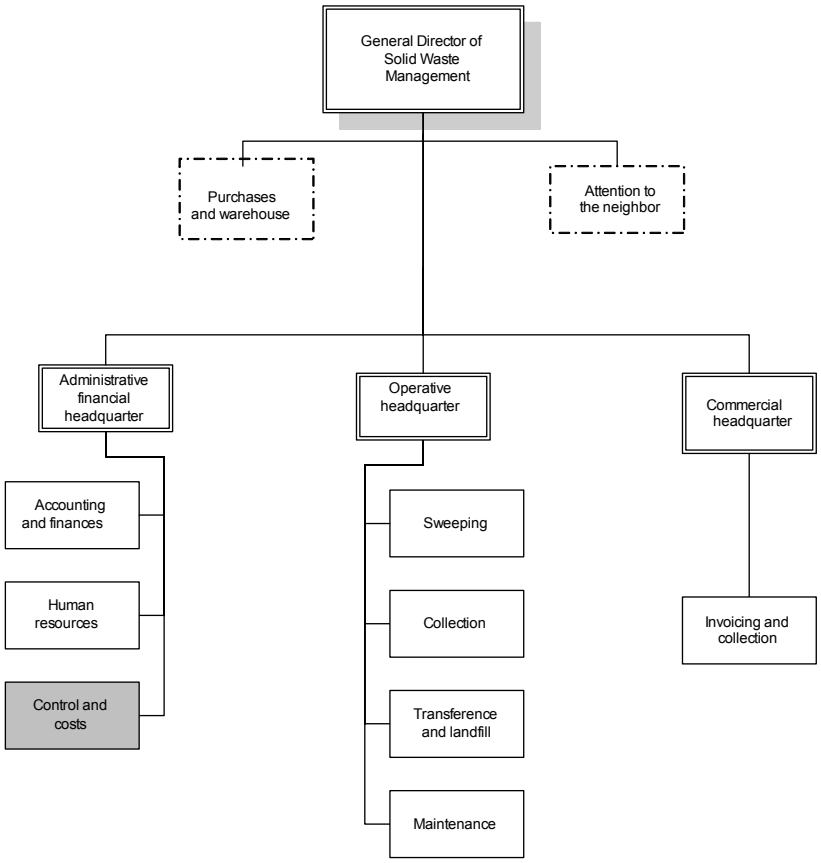
It is proposed to structure the Executive Unit of the Master Plan. This agency will have as objective the implementation of the Master Plan and the achievement of the goals proposed, as well as to strengthen and to facilitate the coordination among the three government levels, with the purpose of protecting the aquatic environment on the coast of Quintana Roo state.

It is recommended that this Executive Unit be under the coordination of SEDUMA, because this is the governing organ of urban development and environmental management at the state level.

72. Restructuring of municipal executing bodies of SWM

In the figure below appears the organizational structure proposed for SWM in the municipality of Othon P. Blanco.

Municipality of Othon P Blanco
Management of Solid Waste
Organizational Structure Proposed



Due to the importance of the SWM on the protection to health and to the preservation of natural resources, as well as its proportion on the municipal budget, it is significant to privilege the hierarchy of the administrative unit in charge of rendering the service.

The creation of a General Office for Solid Waste Management that depends directly from the bureau of the Mayor is proposed. The decision-making at a higher political level will make easier the implementation of any changes and adjustments that are raised on the Master Plan.

Purchase and Storehouse:	Oriented to give support to the unity of Maintenance with the purpose of augmenting the availability of the vehicles and facilitate the activities foreseen in the rendering of the service.
Attention to the neighbor:	To establish an information link and immediate attention with the users of the service.
Administration and Finances:	Manages the resources of the service; prepares the budget and executes it according to the operative needs. The unity of Control and Costs is in charge of verifying that the service achieves the goals of quality of the service (effectiveness) and that the use of resources is efficient.
Operations:	Renders the service according to the norms of quality established in the Regulation.
Commercial:	Offers enough incomes to achieve the sustainability of the service.

8. Establishment of a new SWM system in Costa Maya

It is forecast that number of tourists and population will increase in the future due to tourism development. However, this forecast comprehends great uncertainty, because it is affected various factors, such as economic situation in the country and all over the world, abnormal weather, other competent resorts and so forth. It is risky to construct infrastructures which require a large amount of investment and have little flexibility, such as landfills and transfer stations.

Therefore, it is recommendable at the initial stage to develop an institutional framework and to introduce culture of waste minimization, which are flexible to progress of development, then, to develop required infrastructures later. The following are proposed measures.

81. Establishment of an organizational and institutional framework

The institutional framework is constituted by the "General Law for the Prevention and Integral Management of Waste" (Official Magazine of the Federation, October 08th, 2003 and came into effect on April 08th, 2004); the document of the "Regulation for the Rendering of the Public Service for the Integral Management of Urban Solid Waste" is currently under consideration by the Municipal Council; as well as the "Regulation of Collection, Management and Final Disposal of Solid Waste in Mahahual". It is recommended the approval of the regulation by part of the municipal authorities in Othon P. Blanco.

The community of Mahahual has constituted the "Commission for the Management of Solid Waste" and it is expected the early recognition by part of the Municipality of Othon P. Blanco.

We recommend the organization of the administrative unit of urban development to include the planning and control on the management of solid waste and as well the formulation of a scheme of fair and equitable fees that allow the financial sustainability of the system.

82. Introduction of the culture of minimization

In the community of Mahahual has started the creation of a minimization culture on regards of the integral management of solid waste. Pedestrians place on a separate way their wastes on the stations that have been placed on the coastal streets.

The students of the Tele High school have taken under their responsibility the management of products coming from such separation and have constructed a composter that will treat the organic wastes generated by restaurants.

The group ECOCE, formed by the main companies that bottle beverages in Mexico, has been interested in collecting all PET bottles. The high school is constructing, for such aim, a small gathering centre within the limits of its property.

The authorities of the three government levels coincide in that the minimization is the correct way for the sustainable management of solid waste.

It is recommended to encourage, to facilitate and to establish the culture of minimization using the incentives created in the General Law.

83. Preparation of establishing a firm SWM system

The municipality of Othon P. Blanco has decided to intervene directly in the integral management of solid waste in Mahahual.

Likewise, they have started the pertinent actions in order to obtain support from FONATUR regarding the construction of the sanitary landfill in Costa Maya, with a cost that overpass the 20 million pesos and which includes the mechanical equipment for the operation.

This construction will be part of the infrastructure, necessary for the touristic development of Costa Maya. It is recommended that the competent authorities support the requirement made by the municipality of Othon P. Blanco to FONATUR.

9.3.3.2 Burden Sharing of the Proposed Measures

The following table shows burden sharing of the proposed measures among the stakeholders.

Table 9-39: Burden Sharing of the Proposed Measures

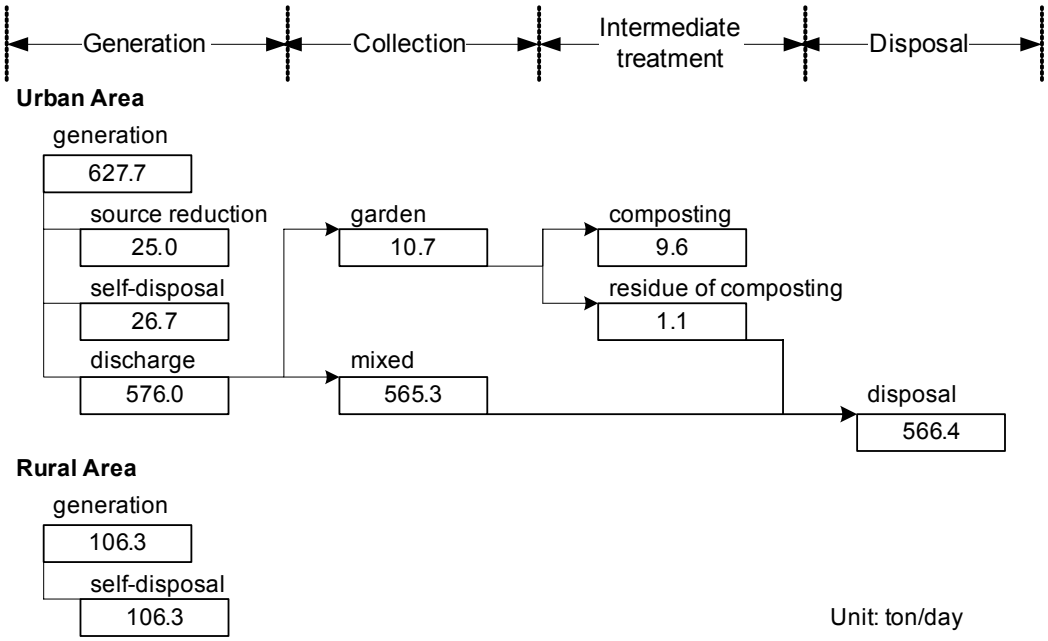
Stakeholders / *Proposed Measures*	*Federal*	*State*	*Municipal*	*Private sector/ NGO*	*Citizens*
symbols	*R responsible, S supporting, P participation/cooperation*				
11. Focusing on the urban area			*R*		
21. Flexible arrangement of collection rate			*R*		
22. Flexible arrangement of final disposal manners			*R*		
31. Environmental education on waste minimization *311. Environmental education and recycling activities in schools* *312. Environmental education and recycling activities in communities* *313. Advertisement of importance of waste minimization through public institutions and/or mass media*		*R*	*R*	*P*	*P*
32. Promotion of backyard composting *321. Preparing and distributing materials how to make compost from garden waste* *322. Establishing visit instruction system of composting* *333. Demonstrating composting in public institutions*		*S*	*R*	*P*	*P*
33. Pruning waste composting		*S*	*R*	*P*	
34. Setting of Waste Minimization Rate		*S*	*R*		
41. Income improvement *411. General application of service charges* *412. Realistic service charges and income improvement* *413. Timely billing and payment facility* *414. Control of bill collection* *415. Specific use of income*			*R*	*P*	*P*
42. Cost reduction *421. Improvement of waste collection works* *422. Constant monitoring*			*R*	*P*	
51. Establishment an information system for the integral management	*R*	*R*	*R*		
61. Formulation of a municipal regulation on SWM		*S*	*R*		
62. Formulation of rules for public-private partnership		*S*	*R*		
71. Establishment of a specialized administrative unit in SEDUMA		*R*			
72. Restructuring of municipal executing bodies of SWM			*R*		
81. Establishment of an organizational and institutional framework *82. Introduction of culture of waste minimization* *83. Preparation of establishing of a firm SWM system*		*S*	*R*	*P*	*P*

9.3.4 Waste Stream

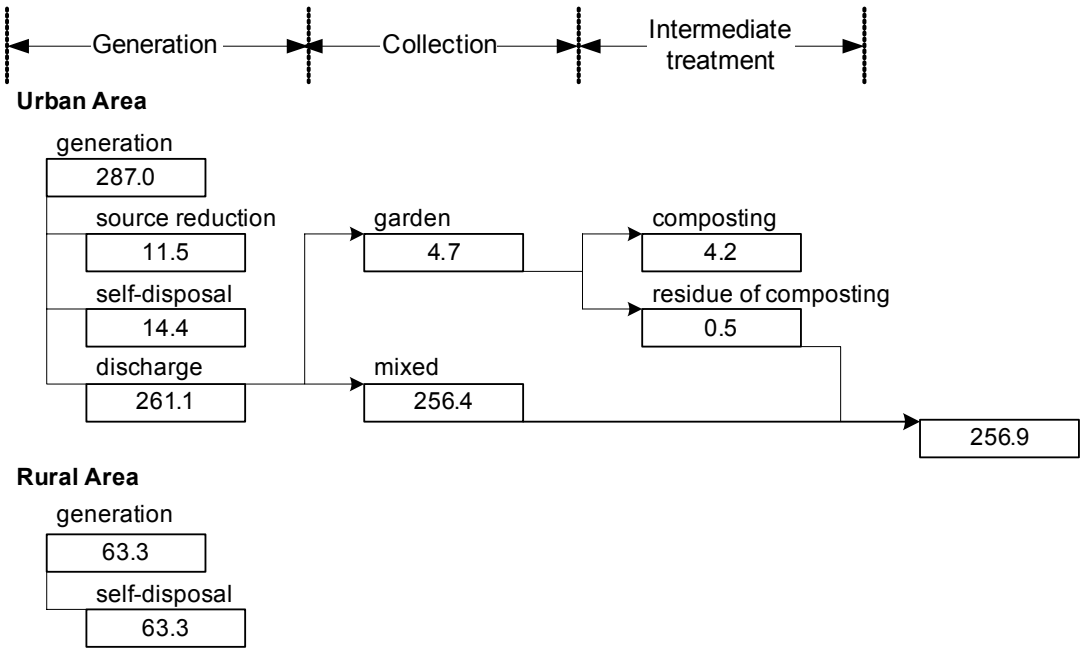
This section describes waste streams of the Master Plan.

a. Waste Steam in Year 2007

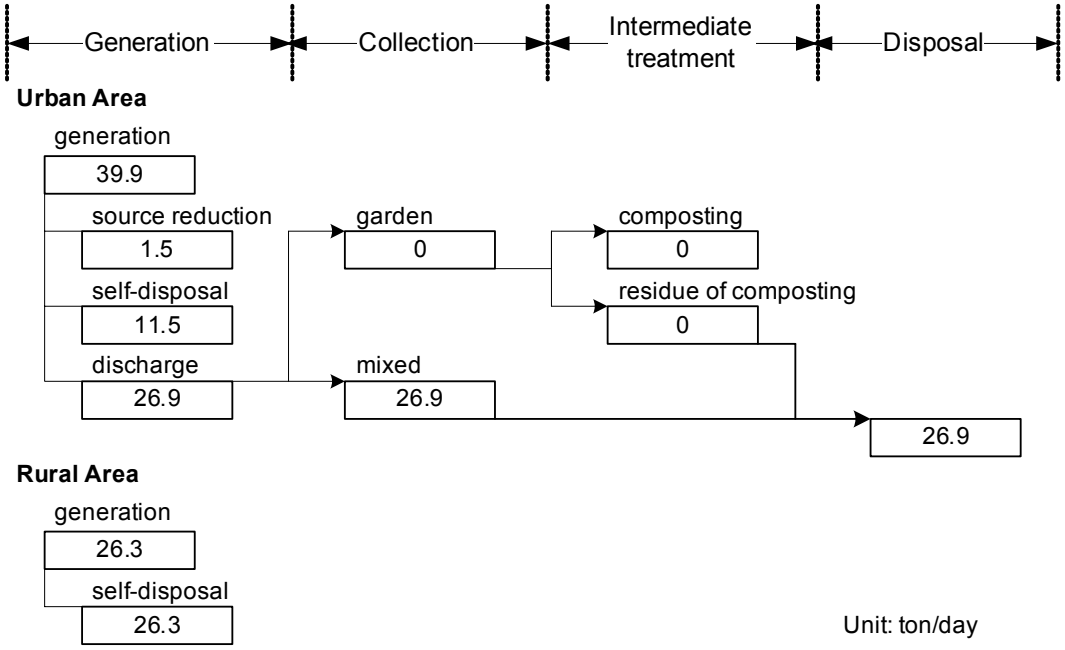
a.1 Whole Study Area in Year 2007



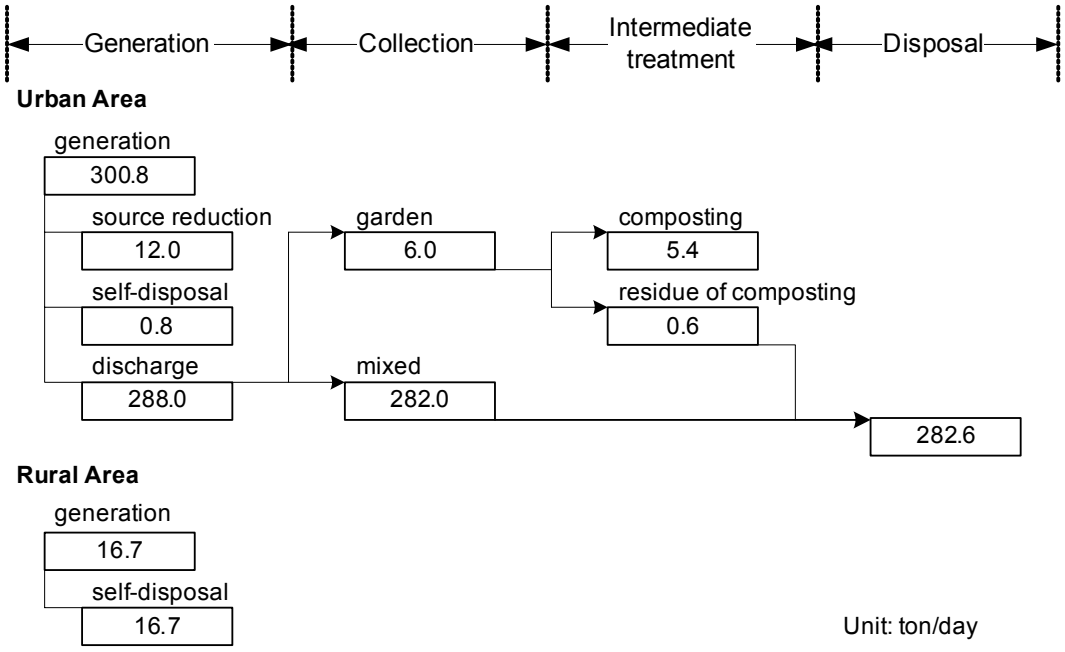
a.2 Othon P Blanco in Year 2007



a.3 Felipe C Puerto in Year 2007

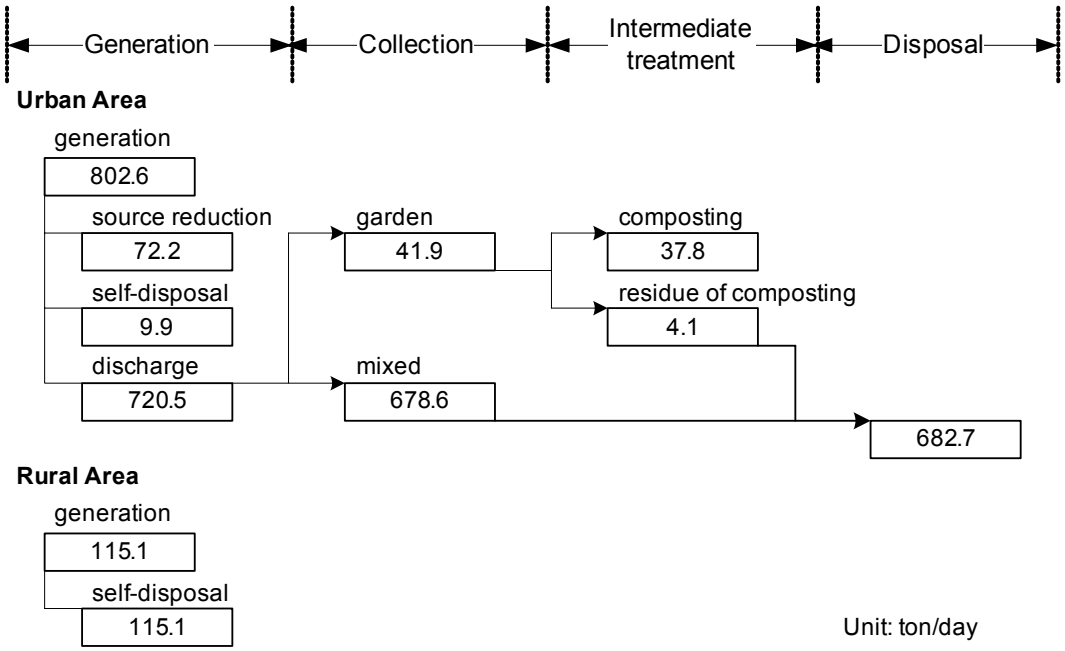


a.4 Solidaridad in Year 2007

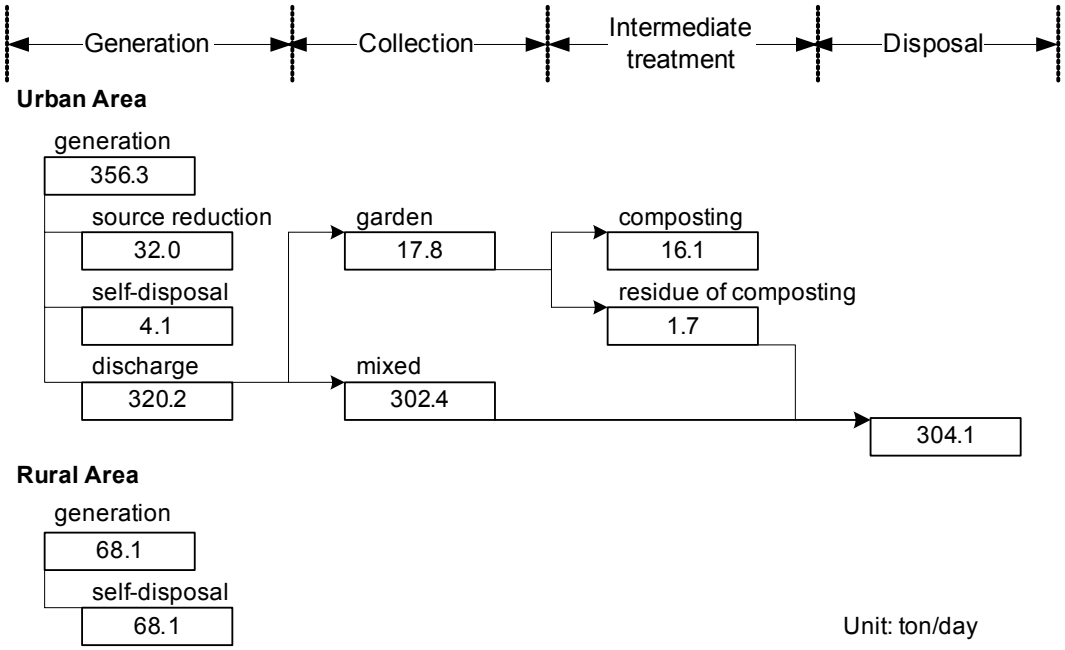


b. Waste Stream in Year 2011

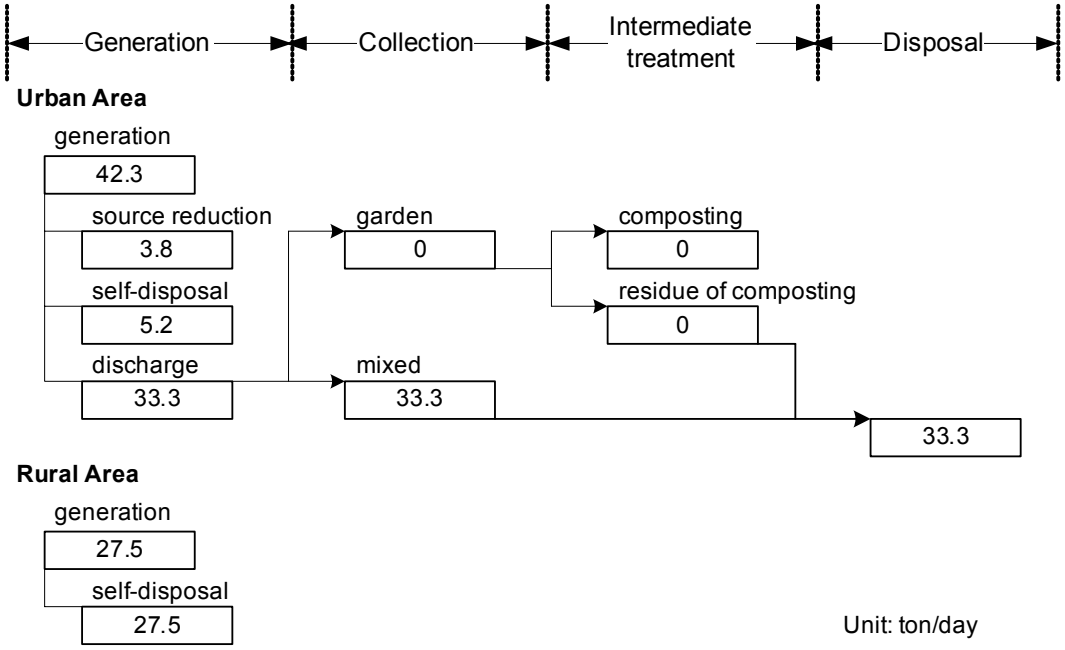
b.1 Whale Study Area in Year 2011



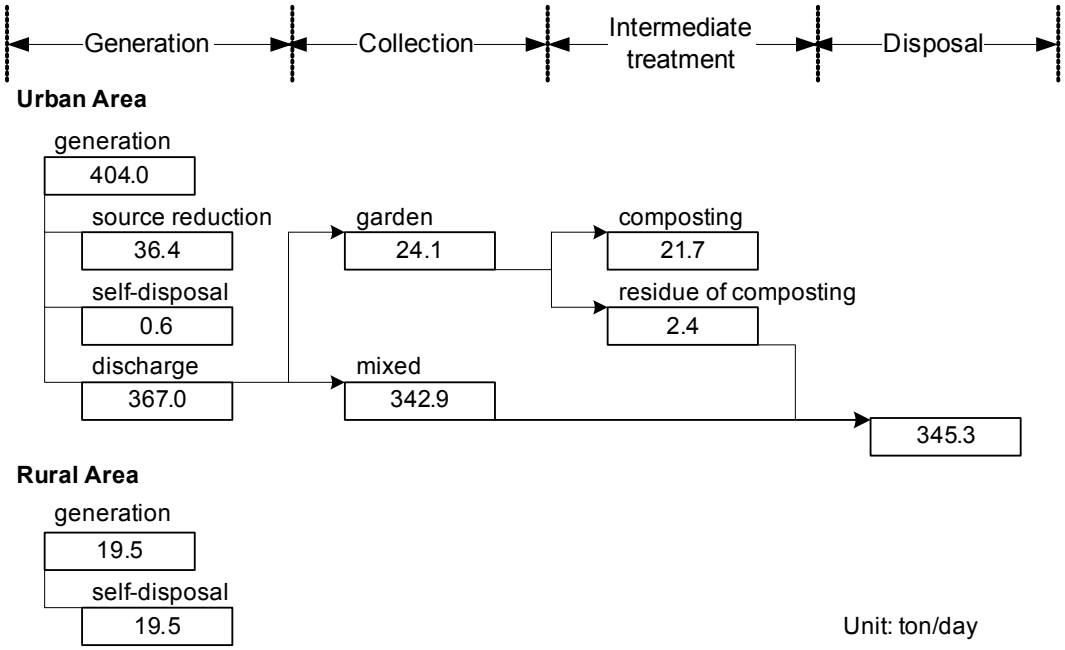
b.2 Othon P Blanco in Year 2011



b.3 Felipe C Puerto in Year 2011

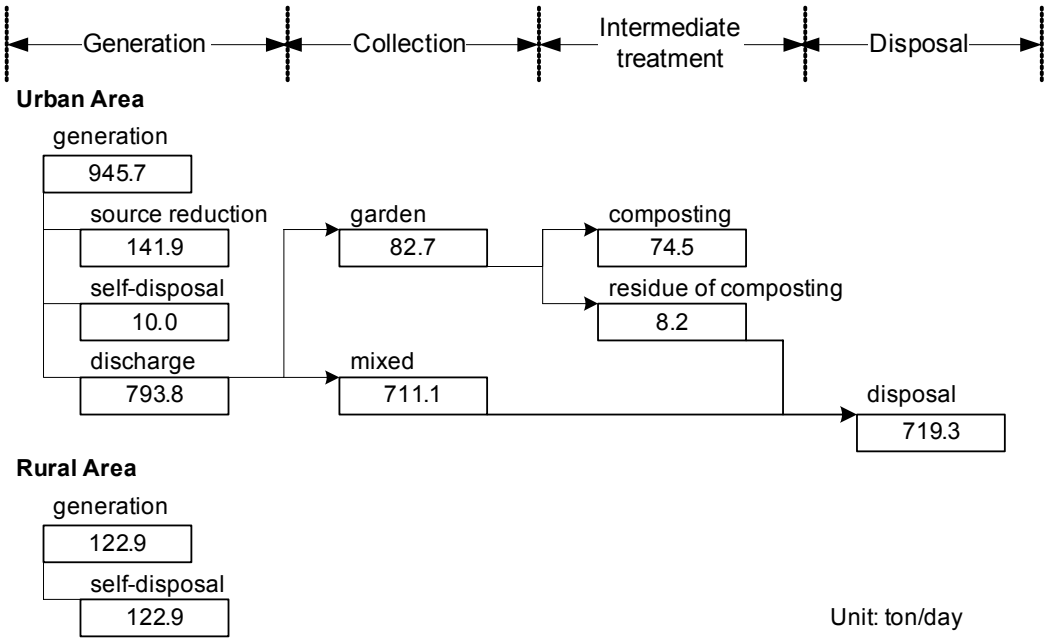


b.4 Solidaridad in Year 2011

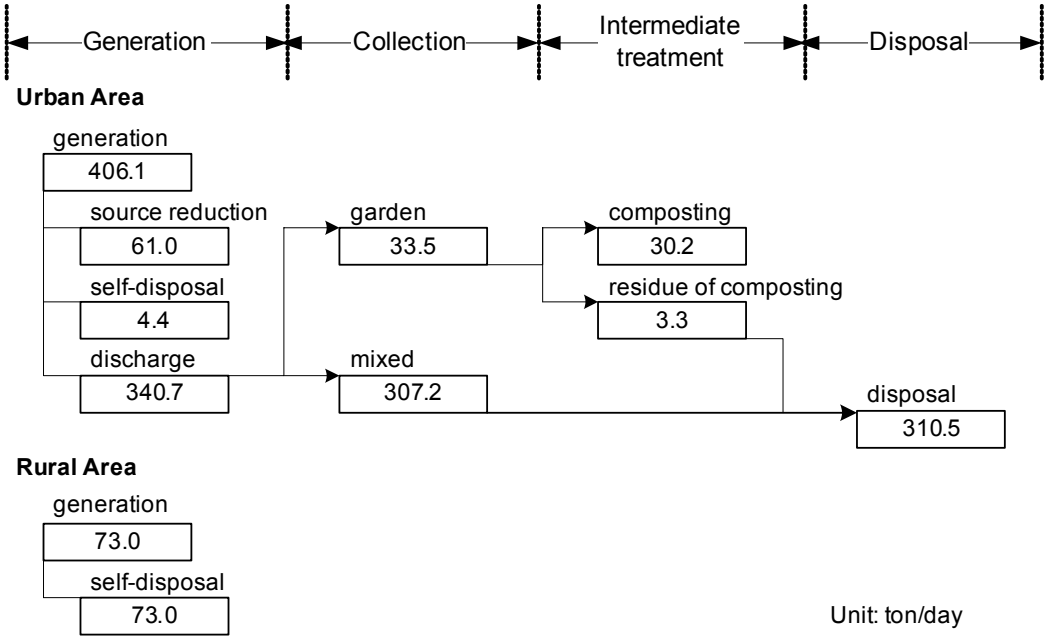


c. Waste Stream in Year 2015

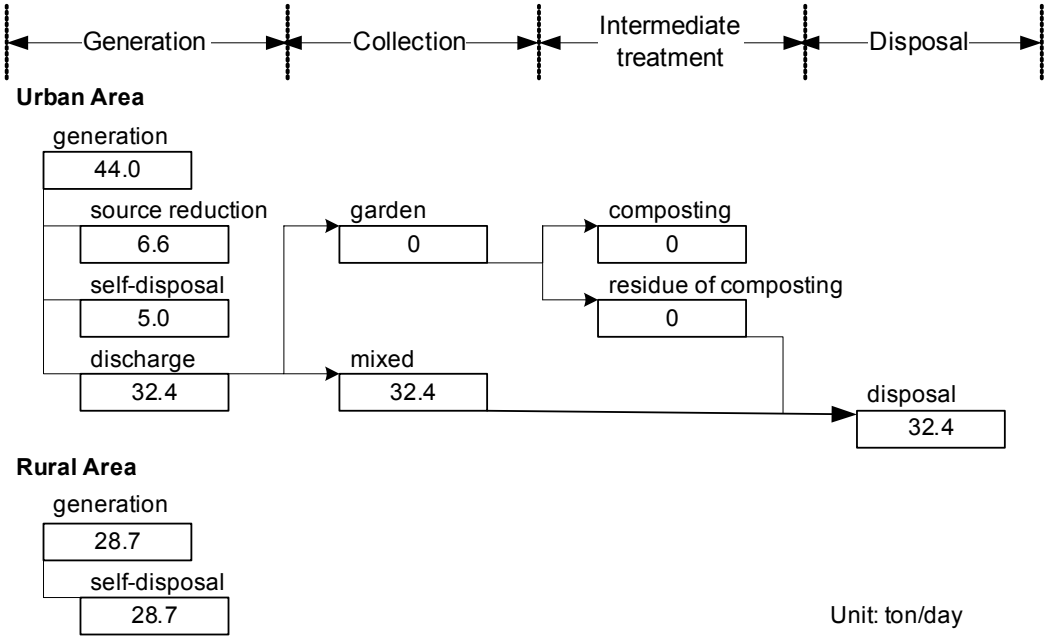
c.1 Whole Study Area in Year 2015



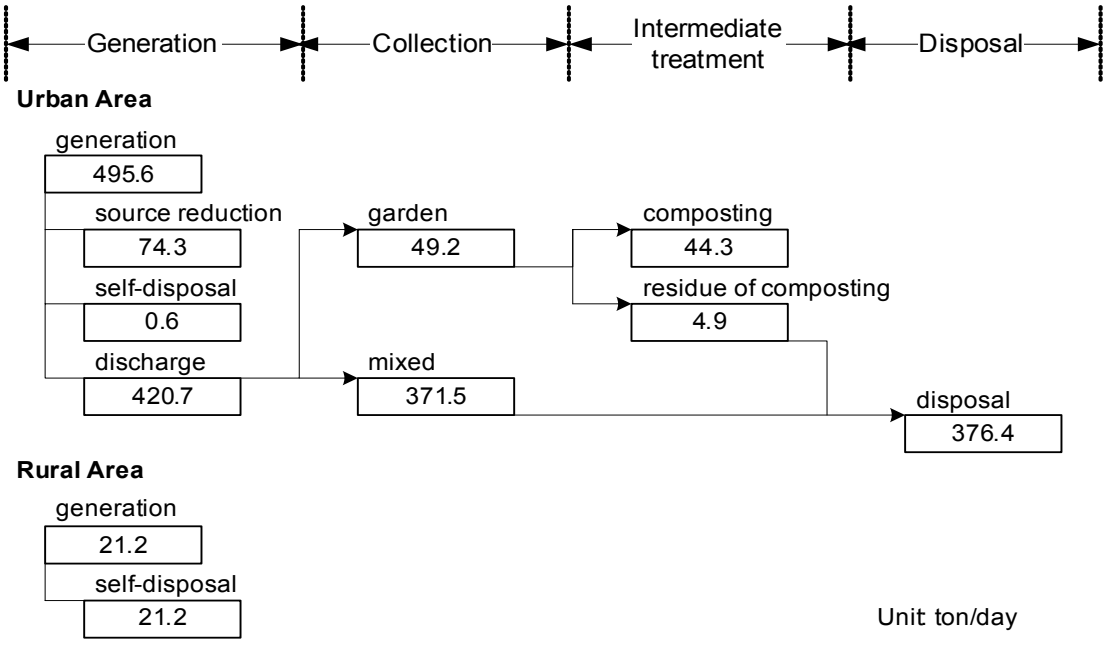
c.2 Othon P Blanco in Year 2015



c.3 Felipe C Puerto in Year 2015



c.4 Solidaridad in Year 2015



9.3.5 Cost Estimation

Total cost required for implementation of the Master Plan is shown in the following tables.

Table 9-40: Cost of the SWM Master Plan (Whole Study Area)

Unit: 1,000 pesos

Item	Short				Middle				Long				Total
	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	
Source reduction	0	1,193	749	852	1,716	1,121	2,421	3,156	4,768	4,017	4,366	3,957	28,316
Collection	34,001	54,560	48,763	58,608	54,670	56,298	57,915	69,421	74,547	67,694	73,876	70,477	720,830
Investment	11,187	23,507	13,475	17,545	11,176	10,483	9,724	17,963	23,155	15,378	20,207	14,960	188,760
O&M	22,814	31,053	35,288	41,063	43,494	45,815	48,191	51,458	51,392	52,316	53,669	55,517	532,070
Recycling (compost)	0	0	4,818	1,683	2,596	2,596	4,070	4,070	4,983	8,899	7,579	7,579	48,873
Investment	0	0	3,135	0	704	352	1,408	704	1,045	4,543	2,101	1,397	15,389
O&M	0	0	1,683	1,683	1,892	2,244	2,662	3,366	3,938	4,356	5,478	6,182	33,484
Final disposal	13,348	15,927	17,949	21,377	25,282	24,167	25,436	33,861	28,118	26,794	27,300	33,446	293,004
Investment	0	0	0	0	2,486	0	0	7,600	1,865	0	0	5,700	17,650
O&M	13,348	15,927	17,949	21,377	22,796	24,167	25,436	26,261	26,253	26,794	27,300	27,746	275,354
Sub-total	47,349	71,680	72,279	82,520	84,264	84,182	89,842	110,508	112,416	107,404	113,121	115,459	1,091,023
Investment	11,187	23,507	16,610	17,545	14,366	10,835	11,132	26,267	26,065	19,921	22,308	22,057	221,799
O&M	36,162	48,173	55,669	64,975	69,898	73,347	78,710	84,241	86,351	87,483	90,813	93,402	869,224
administration (10% of O&M))	3,616	4,818	5,567	6,498	6,990	7,335	7,872	8,425	8,636	8,748	9,081	9,341	86,927
Total	50,965	76,498	77,846	89,018	91,254	91,517	97,714	118,933	121,052	116,152	122,202	124,800	1,177,950
Investment	11,187	23,507	16,610	17,545	14,366	10,835	11,132	26,267	26,065	19,921	22,308	22,057	221,799
O&M	39,778	52,991	61,236	71,473	76,888	80,682	86,582	92,666	94,987	96,231	99,894	102,743	956,151

Table 9-41: Cost of the SWM Master Plan (Othon P Blanco)

Unit: 1,000 pesos

Item	Short				Middle				Long				Total
	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	
Source reduction	0	576	356	402	805	516	1,138	1,460	2,177	1,819	1,962	1,748	12,959
Collection	13,552	26,378	24,156	30,019	29,238	27,082	28,413	29,073	35,365	31,306	35,442	35,244	345,268
Investment	3,355	12,309	8,239	11,187	8,943	6,358	6,721	6,017	12,309	8,250	11,957	10,835	106,480
O&M	10,197	14,069	15,917	18,832	20,295	20,724	21,692	23,056	23,056	23,056	23,485	24,409	238,788
Recycling (compost)	0	0	3,212	1,122	1,122	1,122	2,035	2,035	1,683	4,686	3,509	3,157	23,683
Investment	0	0	2,090	0	0	0	704	352	0	2,794	1,056	352	7,348
O&M	0	0	1,122	1,122	1,122	1,122	1,331	1,683	1,683	1,892	2,453	2,805	16,335
Final disposal	6,107	6,891	7,541	9,616	12,899	11,023	11,598	13,469	13,626	11,903	12,035	13,328	130,036
Investment	0	0	0	0	2,486	0	0	1,593	1,865	0	0	1,195	7,139
O&M	6,107	6,891	7,541	9,616	10,413	11,023	11,598	11,876	11,761	11,903	12,035	12,133	122,897
Sub-total	19,659	33,845	35,265	41,159	44,064	39,743	43,184	46,037	52,851	49,714	52,948	53,477	511,946
Investment	3,355	12,309	10,329	11,187	11,429	6,358	7,425	7,962	14,174	11,044	13,013	12,382	120,967
O&M	16,304	21,536	24,936	29,972	32,635	33,385	35,759	38,075	38,677	38,670	39,935	41,095	390,979
administration (10% of O&M))	1,630	2,154	2,494	2,997	3,264	3,339	3,576	3,808	3,868	3,867	3,994	4,110	39,101
Total	21,289	35,999	37,759	44,156	47,328	43,082	46,760	49,845	56,719	53,581	56,942	57,587	551,047
Investment	3,355	12,309	10,329	11,187	11,429	6,358	7,425	7,962	14,174	11,044	13,013	12,382	120,967
O&M	17,934	23,690	27,430	32,969	35,899	36,724	39,335	41,883	42,545	42,537	43,929	45,205	430,080

Table 9-42: Cost of the Master Plan (Felipe C Puerto)

Unit: 1,000 pesos

Item	Short				Middle				Long				Total
	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	
Source reduction	0	94	49	50	101	54	150	199	259	210	214	169	1,549
Collection	2,090	5,302	1,936	3,542	2,420	2,420	2,420	5,148	4,664	2,420	3,542	2,420	38,324
Investment	1,122	3,366	0	1,122	0	0	0	2,233	2,244	0	1,122	0	11,209
O&M	968	1,936	1,936	2,420	2,420	2,420	2,420	2,915	2,420	2,420	2,420	2,420	27,115
Recycling (compost)	0	0	0	0	0	0	0	0	0	0	0	0	0
Investment	0	0	0	0	0	0	0	0	0	0	0	0	0
O&M	0	0	0	0	0	0	0	0	0	0	0	0	0
Final disposal	151	225	379	465	461	514	516	583	570	570	570	568	5,572
Investment	0	0	0	0	0	0	0	0	0	0	0	0	0
O&M	151	225	379	465	461	514	516	583	570	570	570	568	5,572
Sub-total	2,241	5,621	2,364	4,057	2,982	2,988	3,086	5,930	5,493	3,200	4,326	3,157	45,445
Investment	1,122	3,366	0	1,122	0	0	0	2,233	2,244	0	1,122	0	11,209
O&M	1,119	2,255	2,364	2,935	2,982	2,988	3,086	3,697	3,249	3,200	3,204	3,157	34,236
administration (10% of O&M))	112	226	236	294	298	299	309	370	325	320	320	316	3,425
Total	2,353	5,847	2,600	4,351	3,280	3,287	3,395	6,300	5,818	3,520	4,646	3,473	48,870
Investment	1,122	3,366	0	1,122	0	0	0	2,233	2,244	0	1,122	0	11,209
O&M	1,231	2,481	2,600	3,229	3,280	3,287	3,395	4,067	3,574	3,520	3,524	3,473	37,661

Table 9-43: Cost of the Master Plan

Unit: 1,000 pesos

Item	Short				Middle				Long				Total
	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	
Source reduction	0	523	344	400	810	551	1,133	1,497	2,332	1,988	2,190	2,040	13,808
Collection	18,359	22,880	22,671	25,047	23,012	26,796	27,082	35,200	34,518	33,968	34,892	32,813	337,238
Investment	6,710	7,832	5,236	5,236	2,233	4,125	3,003	9,713	8,602	7,128	7,128	4,125	71,071
O&M	11,649	15,048	17,435	19,811	20,779	22,671	24,079	25,487	25,916	26,840	27,764	28,688	266,167
Recycling (compost)	0	0	1,606	561	1,474	1,474	2,035	2,035	3,300	4,213	4,070	4,422	25,190
Investment	0	0	1,045	0	704	352	704	352	1,045	1,749	1,045	1,045	8,041
O&M	0	0	561	561	770	1,122	1,331	1,683	2,255	2,464	3,025	3,377	17,149
Final disposal	7,090	8,811	10,029	11,296	11,922	12,630	13,322	19,808	13,922	14,321	14,695	19,550	157,396
Investment	0	0	0	0	0	0	0	6,006	0	0	0	4,505	10,511
O&M	7,090	8,811	10,029	11,296	11,922	12,630	13,322	13,802	13,922	14,321	14,695	15,045	146,885
Sub-total	25,449	32,214	34,650	37,304	37,218	41,451	43,572	58,540	54,072	54,490	55,847	58,825	533,632
Investment	6,710	7,832	6,281	5,236	2,937	4,477	3,707	16,071	9,647	8,877	8,173	9,675	89,623
O&M	18,739	24,382	28,369	32,068	34,281	36,974	39,865	42,469	44,425	45,613	47,674	49,150	444,009
administration (10% of O&M))	1,874	2,438	2,837	3,207	3,428	3,697	3,987	4,247	4,443	4,561	4,767	4,915	44,401
Total	27,323	34,652	37,487	40,511	40,646	45,148	47,559	62,787	58,515	59,051	60,614	63,740	578,033
Investment	6,710	7,832	6,281	5,236	2,937	4,477	3,707	16,071	9,647	8,877	8,173	9,675	89,623
O&M	20,613	26,820	31,206	35,275	37,709	40,671	43,852	46,716	48,868	50,174	52,441	54,065	488,410

9.3.6 Financial Analysis

9.3.6.1 Financial Analysis

a. Scenarios

For the purpose of financial analyses, three basic scenarios were set for each municipality and also for the Study Area as a whole. The basic scenarios were differentiated by the assumed monthly service charges as follows:

Scenario 1: Household 30 Pesos, business 100 Pesos

Scenario 2: Household 40 Pesos, business 150 Pesos

Scenario 3: Household 50 Pesos, business 200 Pesos

Within each scenario, the number of business firms was varied as a proportion of the number of households, and the bill collection ratio was assumed to increase year by year.

b. Results

b.1 Othon P. Blanco

Financial self-sufficiency and viability of SWM would be achieved when service charges were assumed to be 50 Pesos per month for households and 200 Pesos per month for business firms, which were assumed to comprise 15% of the number of households, and a bill collection efficiency of 90% from 2009 on. The resulting FIRR was 18.9%.

b.2 Felipe Carrillo Puerto

Financial self-sufficiency and viability of SWM would be achieved when service charges were assumed to be 40 Pesos per month for households and 150 Pesos (100 Pesos) per month for business firms, which were assumed to comprise 15% of the number of households, and a bill collection efficiency of 90% from 2009 on. The resulting FIRR was 37.4 % (10.7%).

b.3 Solidaridad

Financial self-sufficiency and viability of SWM would be achieved when service charges were assumed to be 50 Pesos per month for households and 200 Pesos per month for business firms, which were assumed to comprise 15% of the number of households, and a bill collection efficiency of 90% from 2009 on. The resulting FIRR was 11.4%.

b.4 Study Area

Financial self-sufficiency and viability of SWM would be achieved when service charges were assumed to be 50 Pesos per month for households and 200 Pesos per month for business

firms, which were assumed to comprise 15% of the number of households, and a bill collection efficiency of 90% from 2009 on. The resulting FIRR was 18.1%.

c. Comments

Assuming that even when service charges are applied on all waste generators, if political considerations rule out service charges higher than 30 Pesos per month for households and 100 Pesos per month for business firms, and assuming that business firms comprise the minimum or 10% of the number of households, each municipality, except Felipe Carrillo Puerto, would incur financial deficit in every year of the Master Plan period and will have to apply general funds to SWM as indicated in the following Table.

Table 9-44: SWM Financial Deficit with Service Charges $30 Hholds & $100 Business

Year	OPB	FCP	Solidaridad	Study Area
2004	15.93	1.40	23.30	40.64
2005	25.98	4.20	25.55	55.73
2006	22.50	0.24	23.28	46.02
2007	23.68	1.37	21.07	46.11
2008	22.17	0	16.22	38.19
2009	15.15	0	17.50	32.26
2010	17.15	0	17.75	34.56
2011	19.20	2.54	31.14	52.88
2012	25.03	2.02	25.03	52.09
2013	20.86	0	23.73	44.29
2014	23.19	0.78	23.46	47.43
2015	22.80	0	24.75	47.12

In the case of Othon P. Blanco when service charges are 30 Pesos per month for households and 100 Pesos per month for businesses, the largest required amounts of 25.98 Million Pesos in 2005 and 25.03 Million Pesos in 2012, are not much higher than the nearly 25 Million Pesos spent on SWM in 2002, but the quality of service will be much improved.

In the case of Felipe Carrillo Puerto, even with service charges of 30 Pesos per month for households and 100 Pesos per month for businesses, SWM can produce some financial surpluses in 2008, 2009, 2010, 2013 and 2015.

In the case of Solidaridad when service charges are 30 Pesos per month for households and 100 Pesos per month for businesses, the required application of general funds to SWM would range from 16.22 Million Pesos in 2008 to 31.14 Million Pesos in 2011.

For the Study Area as a whole when service charges are 30 Pesos per month for households and 100 Pesos per month for businesses, the required application of general funds to SWM would range from 32.26 Million Pesos in 2009 to 55.73 Million Pesos in 2005.

9.3.6.2 Financial Self-sufficiency or Revenue Shortfall

From the analysis conducted and presented above, the proposed SWM Master Plan can be financially self-sufficient or may require the use of general funds, depending on the political and management decisions taken and the resulting conditions. The basic assumption is that service charges, albeit low, will be imposed on all solid waste generators. Then, the use of general funds should not be equated with the case "without the Master Plan", as even when the use of general funds is needed, it will be required only to fill the gap between the estimated costs and the revenues estimated under a set of assumptions. And the SWM service will be much improved when compared with the case "without the Master Plan".

As already presented above, financial self-sufficiency would be achieved when all waste generators pay for the SW service at the tune of 50 Pesos per month for households and 200 Pesos per month for business firms. On the other hand, the required use of general funds was estimated by assuming the lowest SW service charges, that is, 30 Pesos per month for households and 100 Pesos per month for business firms, which were assumed to comprise 10% of the number of households.

9.3.7 The Solid Waste Management Master Plan

This section summarizes the Solid Waste Management Master Plan described above in the following tables.

Table 9-45: The SWM Master Plan (Whole Study Area)

Item	unit	Present	Short				Middle				Long				
		2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	
1. Population															
population	nos.	333,328	364,986	431,638	468,473	505,308	543,476	581,644	619,811	648,326	676,841	705,356	733,871	762,386	
household	nos.	78,615	86,082	101,801	110,489	119,176	128,178	137,180	146,182	152,907	159,632	166,358	173,083	179,808	
2. Waste amount															
1) At source															
generation	ton/day	426.1	465.5	539.7	583.4	627.7	673.8	720.4	767.5	802.6	838.1	873.5	909.6	945.7	
sorce reduction	ton/day	0	0	10.9	17.5	25	40.5	50.5	61.5	72.2	100.6	113.5	127.3	141.9	
self-disposal	ton/day	106.2	124.3	100.9	71.3	26.7	26.9	20.5	17.3	9.9	9.8	9.8	9.9	10	
discharge	ton/day	319.9	341.2	427.9	494.6	576	606.4	649.4	688.7	720.5	727.7	750.2	772.4	793.8	
2) Collection															
mixed waste	ton/day	319.9	341.2	427.9	489.7	565.3	589.1	624.5	655.5	678.6	676.7	689.3	701	711.1	
garden waste	ton/day	0	0	0	4.9	10.7	17.3	24.9	33.2	41.9	51	60.9	71.4	82.7	
3) Disposal															
disposal	ton/day	319.9	341.2	427.9	490.3	566.4	590.8	627	658.8	682.7	681.9	695.5	708.1	719.3	
3. Waste minimization	%	0	0	2	4	6	9	10	12	14	18	20	22	24	
source reduction	%	0	0	2	3	4	6	7	8	9	12	13	14	15	
recycling	%	0	0	0	1	2	3	3	4	5	6	7	8	9	
4. Technical System															
1) Source reduction															
participant (household)	%	0%	0%	11%	16%	21%	32%	37%	43%	48%	64%	69%	75%	80%	
participant (household)	nos.	-	0	10,860	17,679	25,424	41,018	51,214	62,370	73,395	102,166	115,341	129,236	143,848	
purchase of container	nos.	-	0	10,860	6,819	7,745	15,594	10,196	22,016	28,704	43,335	36,514	39,685	35,964	
2) Collection															
collection rate	%	75	73	81	87	96	96	97	98	99	99	99	99	99	
compactor (required)	nos.	-	47	64	70	81	86	89	93	97	96	97	98	100	
dump truck (required)	nos.	-	0	0	3	4	4	6	7	10	11	12	14	16	
compactor (purchase)	nos.	-	10	21	10	15	10	8	8	14	20	11	16	12	
dump truck (purchase)	nos.	-	0	0	3	1	0	2	1	3	1	4	3	2	
3) Recycling (compost)															
wheel loader (required)	nos.	-	0	0	3	3	4	4	6	6	7	9	11	11	
shredder (required)	nos.	-	0	0	3	3	3	4	4	6	7	7	9	11	
wheel loader (purchase)	nos.	-	0	0	3	0	1	0	2	0	1	5	2	1	
shredder (purchase)	nos.	-	0	0	3	0	0	1	0	2	1	3	2	2	
4) Final disposal															
phased development			several levels of landfilling are to be adopted depending on community size												
5. SWM cost															Total
source reduction	1000pesos	-	0	1,193	749	852	1,716	1,121	2,421	3,156	4,768	4,017	4,366	3,957	28,316
collection	1000pesos	-	34,001	54,560	48,763	58,608	54,670	56,298	57,915	69,421	74,547	67,694	73,876	70,477	720,830
recycling (compost)	1000pesos	-	0	0	4,818	1,683	2,596	2,596	4,070	4,070	4,983	8,899	7,579	7,579	48,873
final disposal	1000pesos	-	13,348	15,927	17,949	21,377	25,282	24,167	25,436	33,861	28,118	26,794	27,300	33,446	293,004
sub-total	1000pesos	-	47,349	71,680	72,279	82,520	84,264	84,182	89,842	110,508	112,416	107,404	113,121	115,459	1,091,023
administration	1000pesos	-	3,616	4,818	5,567	6,498	6,990	7,335	7,872	8,425	8,636	8,748	9,081	9,341	86,927
total	1000pesos	-	50,965	76,498	77,846	89,018	91,254	91,517	97,714	118,933	121,052	116,152	122,202	124,800	1,177,950
6. Revenue (1)															
household	1000pesos	-	5,165	18,324	33,147	50,054	65,371	74,077	78,938	82,570	86,201	89,833	93,465	97,096	774,241
business entity	1000pesos	-	21,693	29,319	35,799	38,613	41,530	44,446	47,363	49,542	51,721	53,900	56,079	58,258	528,263
other sources	1000pesos	-	0	0	0	0	0	0	0	0	0	0	0	0	0
total	1000pesos	-	26,858	47,643	68,946	88,667	106,901	118,523	126,301	132,112	137,922	143,733	149,544	155,354	1,302,504
7. Balance															
balance	1000pesos		-24,107	-28,855	-8,900	-0,351	15,646	27,007	28,587	13,180	16,870	27,580	27,342	30,554	124,553

Note: (1) Service charges were assumed to be 50 pesos per month for households and 200 pesos per month for business firms.

Table 9-46: The SWM Master Plan (Othon P Blnaco)

Item	unit	Present	Short				Middle				Long				
		2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	
1. Population															
population	nos.	170,538	189,359	208,179	224,676	241,173	257,670	274,167	290,664	300,821	310,978	321,135	331,292	341,449	
household	nos.	40,221	44,660	49,099	52,990	56,880	60,771	64,662	68,553	70,948	73,344	75,739	78,135	80,530	
2. Waste amount															
1) At source															
generation	ton/day	208.4	229.1	250	268.5	287	306	325.1	344.2	356.3	368.7	380.9	393.6	406.1	
sorce reduction	ton/day	0	0	5	8	11.5	18.4	22.8	27.6	32	44.3	49.4	55	61	
self-disposal	ton/day	58.3	77	55.8	40.5	14.4	14.8	10.8	7.5	4.1	4.1	4.2	4.3	4.4	
discharge	ton/day	150.1	152.1	189.2	220	261.1	272.8	291.5	309.1	320.2	320.3	327.3	334.3	340.7	
2) Collection															
mixed waste	ton/day	150.1	152.1	189.2	217.8	256.4	265.2	280.7	294.8	302.4	298.9	302.1	305.1	307.2	
garden waste	ton/day	0	0	0	2.2	4.7	7.6	10.8	14.3	17.8	21.4	25.2	29.2	33.5	
3) Disposal															
disposal	ton/day	150.1	152.1	189.2	218.1	256.9	265.9	281.8	296.2	304.1	301.1	304.7	308	310.5	
3. Waste minimization	%	0	0	2	4	6	8	10	12	14	18	20	21	23	
source reduction	%	0	0	2	3	4	6	7	8	9	12	13	14	15	
recycling	%	0	0	0	1	2	2	3	4	5	6	7	7	8	
4. Technical System															
1) Source reduction															
participant (household)	%	0%	0%	11%	16%	21%	32%	37%	43%	48%	64%	69%	75%	80%	
participant (household)	nos.	-	0	5,238	8,478	12,135	19,448	24,141	29,249	34,055	46,941	52,512	58,341	64,425	
purchase of container	nos.	-	0	5,238	3,240	3,657	7,313	4,693	10,346	13,284	19,783	16,541	17,835	15,885	
2) Collection															
collection rate	%	72	66	77	84	95	95	96	98	99	99	99	99	99	
compactor (required)	nos.	-	21	29	31	37	40	40	42	43	43	43	43	44	
dump truck (required)	nos.	-	0	0	2	2	2	3	3	5	5	5	6	7	
compactor (purchase)	nos.	-	3	11	6	10	8	5	6	4	11	6	10	9	
dump truck (purchase)	nos.	-	0	0	2	0	0	1	0	2	0	2	1	1	
3) Recycling (compost)															
wheel loader (required)	nos.	-	0	0	2	2	2	2	3	3	3	4	5	5	
shredder (required)	nos.	-	0	0	2	2	2	2	2	3	3	3	4	5	
wheel loader (purchase)	nos.	-	0	0	2	0	0	0	1	0	0	3	1	0	
shredder (purchase)	nos.	-	0	0	2	0	0	0	0	1	0	2	1	1	
4) Final disposal															
phased development			several levels of landfilling are to be adopted depending on community size												
5. SWM cost															Total
source reduction	1000pesos	-	0	576	356	402	805	516	1,138	1,460	2,177	1,819	1,962	1,748	12,959
collection	1000pesos	-	13,552	26,378	24,156	30,019	29,238	27,082	28,413	29,073	35,365	31,306	35,442	35,244	345,268
recycling (compost)	1000pesos	-	0	0	3,212	1,122	1,122	1,122	2,035	2,035	1,683	4,686	3,509	3,157	23,683
final disposal	1000pesos	-	6,107	6,891	7,541	9,616	12,899	11,023	11,598	13,469	13,626	11,903	12,035	13,328	130,036
sub-total	1000pesos	-	19,659	33,845	35,265	41,159	44,064	39,743	43,184	46,037	52,851	49,714	52,948	53,477	511,946
administration	1000pesos	-	1,630	2,154	2,494	2,997	3,264	3,339	3,576	3,808	3,868	3,867	3,994	4,110	39,101
total	1000pesos	-	21,289	35,999	37,759	44,156	47,328	43,082	46,760	49,845	56,719	53,581	56,942	57,587	551,047
6. Revenue (2)															
household	1000pesos	-	2,680	8,838	15,897	23,890	30,993	34,917	37,019	38,312	39,606	40,899	42,193	43,486	358,730
business entity	1000pesos	-	11,254	14,141	17,169	18,429	19,690	20,950	22,211	22,987	23,763	24,539	25,316	26,092	246,541
other sources	1000pesos	-	0	0	0	0	0	0	0	0	0	0	0	0	0
total	1000pesos	-	13,934	22,979	33,066	42,319	50,683	55,867	59,230	61,299	63,369	65,438	67,509	69,578	605,271
7. Balance															
balance	1000pesos		-7,355	-13,020	-4,693	-1,837	3,355	12,785	12,470	11,454	6,650	11,857	10,567	11,991	54,224

Note: (2) Service charges were assumed to be 50 pesos per month for households and 200 pesos per month for business firms.

Table 9-47: The SWM Master Plan (Felipe C Puerto)

Item	unit	Present	Short				Middle				Long				
		2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	
1. Population															
population	nos.	33,025	33,630	34,232	34,699	35,166	35,633	36,100	36,568	36,909	37,250	37,591	37,932	38,273	
household	nos.	7,789	7,932	8,074	8,184	8,294	8,404	8,514	8,625	8,705	8,785	8,866	8,946	9,027	
2. Waste amount															
1) At source															
generation	ton/day	37.1	37.9	38.6	39.1	39.9	40.4	41.1	41.8	42.3	42.7	43.2	43.7	44	
sorce reduction	ton/day	0	0	0.8	1.2	1.5	2.4	2.9	3.4	3.8	5.1	5.7	6.2	6.6	
self-disposal	ton/day	26.3	25.4	19.1	16.4	11.5	11.3	8.9	9	5.2	5.1	5	5	5	
discharge	ton/day	10.8	12.5	18.7	21.5	26.9	26.7	29.3	29.4	33.3	32.5	32.5	32.5	32.4	
2) Collection															
mixed waste	ton/day	10.8	12.5	18.7	21.5	26.9	26.7	29.3	29.4	33.3	32.5	32.5	32.5	32.4	
garden waste	ton/day	0	0	0	0	0	0	0	0	0	0	0	0	0	
3) Disposal															
disposal	ton/day	10.8	12.5	18.7	21.5	26.9	26.7	29.3	29.4	33.3	32.5	32.5	32.5	32.4	
3. Waste minimization	%	0	0	2	3	4	6	7	8	9	12	13	14	15	
source reduction	%	0	0	2	3	4	6	7	8	9	12	13	14	15	
recycling	%	0	0	0	0	0	0	0	0	0	0	0	0	0	
4. Technical System															
1) Source reduction															
participant (household)	%	0%	0%	11%	16%	21%	32%	37%	43%	48%	64%	69%	75%	80%	
participant (household)	nos.	-	0	862	1,310	1,769	2,689	3,178	3,679	4,178	5,623	6,147	6,680	7,222	
purchase of container	nos.	-	0	862	448	459	920	489	1,363	1,809	2,352	1,903	1,942	1,532	
2) Collection															
collection rate	%	29	33	49	57	70	70	77	77	86	86	87	87	87	
compactor (required)	nos.	-	2	4	4	5	5	5	5	6	5	5	5	5	
dump truck (required)	nos.	-	0	0	0	0	0	0	0	0	0	0	0	0	
compactor (purchase)	nos.	-	1	3	0	1	0	0	0	2	2	0	1	0	
dump truck (purchase)	nos.	-	0	0	0	0	0	0	0	0	0	0	0	0	
3) Recycling (compost)															
wheel loader (required)	nos.	-	0	0	0	0	0	0	0	0	0	0	0	0	
shredder (required)	nos.	-	0	0	0	0	0	0	0	0	0	0	0	0	
wheel loader (purchase)	nos.	-	0	0	0	0	0	0	0	0	0	0	0	0	
shredder (purchase)	nos.	-	0	0	0	0	0	0	0	0	0	0	0	0	
4) Final disposal															
phased development			several levels of landfilling are to be adopted depending on community size												
5. SWM cost															Total
source reduction	1000pesos	-	0	94	49	50	101	54	150	199	259	210	214	169	1,549
collection	1000pesos	-	2,090	5,302	1,936	3,542	2,420	2,420	2,420	5,148	4,664	2,420	3,542	2,420	38,324
recycling (compost)	1000pesos	-	0	0	0	0	0	0	0	0	0	0	0	0	0
final disposal	1000pesos	-	151	225	379	465	461	514	516	583	570	570	570	568	5,572
sub-total	1000pesos	-	2,241	5,621	2,364	4,057	2,982	2,988	3,086	5,930	5,493	3,200	4,326	3,157	45,445
administration	1000pesos	-	112	226	236	294	298	299	309	370	325	320	320	316	3,425
total	1000pesos	-	2,353	5,847	2,600	4,351	3,280	3,287	3,395	6,300	5,818	3,520	4,646	3,473	48,870
6. Revenue (3)															
household	1000pesos	-	0,381	1,163	1,964	2,787	3,429	3,678	3,726	3,761	3,795	3,830	3,865	3,900	36,279
business entity	1000pesos	-	1,499	1,744	1,989	2,015	2,042	2,069	2,096	2,115	2,135	2,154	2,174	2,194	24,226
other sources	1000pesos	-	0	0	0	0	0	0	0	0	0	0	0	0	0
total	1000pesos	-	1,880	2,907	3,953	4,802	5,471	5,747	5,822	5,876	5,930	5,984	6,039	6,094	60,505
7. Balance															
balance	1000pesos		-0,473	-2,940	1,353	0,451	2,191	2,460	2,427	-0,424	0,112	2,464	1,393	2,621	11,635

Note: (3) Service charges were assumed to be 40 pesos per month for households and 150 pesos per month for business firms.

Table 9-48: The SWM Master Plan (Solidaridad)

Item	unit	Present	Short				Middle				Long				
		2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	
1. Population															
population	nos.	129,765	141,997	189,227	209,098	228,969	250,173	271,377	292,579	310,596	328,613	346,630	364,647	382,664	
household	nos.	30,605	33,490	44,629	49,316	54,002	59,003	64,004	69,004	73,254	77,503	81,752	86,002	90,251	
2. Waste amount															
1) At source															
generation	ton/day	180.6	198.5	251.1	275.8	300.8	327.4	354.2	381.5	404	426.7	449.4	472.3	495.6	
sorce reduction	ton/day	0	0	5.1	8.3	12	19.7	24.8	30.5	36.4	51.2	58.4	66.1	74.3	
self-disposal	ton/day	21.6	21.9	26	14.4	0.8	0.8	0.8	0.8	0.6	0.6	0.6	0.6	0.6	
discharge	ton/day	159	176.6	220	253.1	288	306.9	328.6	350.2	367	374.9	390.4	405.6	420.7	
2) Collection															
mixed waste	ton/day	159	176.6	220	250.4	282	297.2	314.5	331.3	342.9	345.3	354.7	363.4	371.5	
garden waste	ton/day	0	0	0	2.7	6	9.7	14.1	18.9	24.1	29.6	35.7	42.2	49.2	
3) Disposal															
disposal	ton/day	159	176.6	220	250.7	282.6	298.2	315.9	333.2	345.3	348.3	358.3	367.6	376.4	
3. Waste minimization	%	0	0	2	4	6	9	11	13	15	19	21	23	25	
source reduction	%	0	0	2	3	4	6	7	8	9	12	13	14	15	
recycling	%	0	0	0	1	2	3	4	5	6	7	8	9	10	
4. Technical System															
1) Source reduction															
participant (household)	%	0%	0%	11%	16%	21%	32%	37%	43%	48%	64%	69%	75%	80%	
participant (household)	nos.	-	0	4,760	7,891	11,520	18,881	23,895	29,442	35,162	49,602	56,682	64,215	72,201	
purchase of container	nos.	-	0	4,760	3,131	3,629	7,361	5,014	10,307	13,611	21,200	18,070	19,908	18,547	
2) Collection															
collection rate	%	88	89	89	95	100	100	100	100	100	100	100	100	100	
compactor (required)	nos.	-	24	31	35	39	41	44	46	48	48	49	50	51	
dump truck (required)	nos.	-	0	0	1	2	2	3	4	5	6	7	8	9	
compactor (purchase)	nos.	-	6	7	4	4	2	3	2	8	7	5	5	3	
dump truck (purchase)	nos.	-	0	0	1	1	0	1	1	1	1	2	2	1	
3) Recycling (compost)															
wheel loader (required)	nos.	-	0	0	1	1	2	2	3	3	4	5	6	6	
shredder (required)	nos.	-	0	0	1	1	1	2	2	3	4	4	5	6	
wheel loader (purchase)	nos.	-	0	0	1	0	1	0	1	0	1	2	1	1	
shredder (purchase)	nos.	-	0	0	1	0	0	1	0	1	1	1	1	1	
4) Final disposal															
phased development			several levels of landfilling are to be adopted depending on community size												
5. SWM cost															Total
source reduction	1000pesos	-	0	523	344	400	810	551	1,133	1,497	2,332	1,988	2,190	2,040	13,808
collection	1000pesos	-	18,359	22,880	22,671	25,047	23,012	26,796	27,082	35,200	34,518	33,968	34,892	32,813	337,238
recycling (compost)	1000pesos	-	0	0	1,606	561	1,474	1,474	2,035	2,035	3,300	4,213	4,070	4,422	25,190
final disposal	1000pesos	-	7,090	8,811	10,029	11,296	11,922	12,630	13,322	19,808	13,922	14,321	14,695	19,550	157,396
sub-total	1000pesos	-	25,449	32,214	34,650	37,304	37,218	41,451	43,572	58,540	54,072	54,490	55,847	58,825	533,632
administration	1000pesos	-	1,874	2,438	2,837	3,207	3,428	3,697	3,987	4,247	4,443	4,561	4,767	4,915	44,401
total	1000pesos	-	27,323	34,652	37,487	40,511	40,646	45,148	47,559	62,787	58,515	59,051	60,614	63,740	578,033
6. Revenue (4)															
household	1000pesos	-	2,009	8,033	14,795	22,681	30,092	34,562	37,262	39,557	41,852	44,146	46,441	48,736	370,166
business entity	1000pesos	-	8,439	12,853	15,978	17,497	19,117	20,737	22,357	23,734	25,111	26,488	27,865	29,241	249,417
other sources	1000pesos	-	0	0	0	0	0	0	0	0	0	0	0	0	0
total	1000pesos	-	10,448	20,886	30,773	40,178	49,209	55,299	59,619	63,291	66,963	70,634	74,306	77,977	619,583
7. Balance															
balance	1000pesos		-16,875	-13,766	-6,714	-0,333	8,563	10,151	12,060	0,504	8,448	11,583	13,692	14,237	41,550

Note: (4) Service charges were assumed to be 50 pesos per month for households and 200 pesos per month for business firms.

9.3.8 Implementation Plan

9.3.8.1 Overall Implementation Plan

The following tables show how to implement the Master Plan in Phases.

Table 9-49: Implementation Plan (Phase 1: 2004-2007)

Item	Othon P Blanco	Felipe C Puerto	Solidaridad
1. Basic strategy	• Focusing on the urban area		
2. Technical system			
1) Source reduction	• To begin backyard composting in the all urban groups		
2) Collection & transport	• To begin expansion of collection area • To begin improvement of waste collection works		
3) Intermediate treatment	• To begin pruning waste composting in Urban Group 1 and 5	-	• To begin pruning waste composting in Urban Group 9
4) Final disposal	• To construct a sanitary landfill with leachate control in Urban Group 1 • To improve the dump site in Urban Group 2 up to enclosed dump site • To improve the dump site in Urban Group 4 up to enclosed dump site • To improve the dump site in Urban Group 5 up to landfill with gas control	• To improve the dump site in Urban Group 6 up to enclosed dump site	• To operate existing disposal sites
3. Management system			
1) Planning & operations	• To plan and operate SWM according to the M/P • To follow operation manuals and suggestions made by the Model Projects		
2) Commercial & financial	• To begin improvement of income		
3) Administration	• To establish a specialized administrative unit in SEDUMA • To take action for restructuring of municipal executing bodies of SWM		
4) Monitoring	• To begin monitoring of performance indicators of SWM		
4. Legal & institutional system	• To establish an information system for the integral SWM • To take action for formulation of a municipal regulation on SWM		
5. Public private partnership	• To review existing public private partnership • To formulate rules of public private partnership, if necessary		
6. Citizens participation	• To begin environmental education on waste minimization		
7. Newly developed urban area	• To initiate establishment of a new SWM system in Costa Maya	-	-

Table 9-50: Implementation Plan (Phase 2: 2008-2011)

Item	Othon P Blanco	Felipe C Puerto	Solidaridad
1. Basic strategy	• Focusing on the urban area		
2. Technical system			
1) Source reduction	• To expand backyard composting in the all urban groups		
2) Collection & transport	• To continue expansion of collection area • To continue improvement of waste collection works		
3) Intermediate treatment	• To expand pruning waste composting in Urban Group 1 and 5	-	• To expand pruning waste composting in Urban Group 9
4) Final disposal	• To begin operation of the sanitary landfill with leachate control in Urban Group 1 • To construct and to begin operation of a sanitary landfill with leachate control in Urban Group 5	• To continue to operate the disposal sites	• To construct and to begin operation of a sanitary landfill with leachate control in Urban Group 9
3. Management system			
1) Planning & operations	• To plan and operate SWM according to the M/P • To follow operation manuals and suggestions made by the Model Projects		
2) Commercial & financial	• To continue improvement of income		
3) Administration	• To operate the specialized administrative unit in SEDUMA • To operate restructurized municipal executing bodies of SWM		
4) Monitoring	• To continue monitoring of performance indicators of SWM		
4. Legal & institutional system	• To operate the information system for the integral SWM • To supervise SWM services according to the municipal regulation		
5. Public private partnership	• To review existing public private partnership • To formulate rules of public private partnership, if necessary		
6. Citizens participation	• To continue environmental education on waste minimization		
7. Newly developed urban area	• To establish a firm SWM system in Costa Maya	-	-

Table 9-51: Implementation Plan (Phase 3: 2012-2015)

Item	Othon P Blanco	Felipe C Puerto	Solidaridad
1. Basic strategy	• Focusing on the urban area		
2. Technical system			
1) Source reduction	• To expand backyard composting in the all urban groups		
2) Collection & transport	• To continue expansion of collection area • To continue improvement of waste collection works		
3) Intermediate treatment	• To expand pruning waste composting in Urban Group 1 and 5	-	• To expand pruning waste composting in Urban Group 9
4) Final disposal	• To continue to operate the disposal sites	• To continue to operate the disposal sites	• To continue to operate the disposal sites
3. Management system			
1) Planning & operations	• To plan and operate SWM according to the M/P • To follow operation manuals and suggestions made by the Model Projects		
2) Commercial & financial	• To continue improvement of income		
3) Administration	• To operate the specialized administrative unit in SEDUMA • To operate restructurized municipal executing bodies of SWM		
4) Monitoring	• To continue monitoring of performance indicators of SWM		
4. Legal & institutional system	• To operate the information system for the integral SWM • To supervise SWM services according to the municipal regulation		
5. Public private partnership	• To review existing public private partnership • To formulate rules of public private partnership, if necessary		
6. Citizens participation	• To continue environmental education on waste minimization		
7. Newly developed urban area	• To establish a firm SWM system in Costa Maya	-	-

9.4 Evaluation of the Master Plan

9.4.1 Economic Evaluation

a. Concept of Evaluation

The challenge in the Study Area is "to pursue a sustainable development while balancing preservation of the rich coastal environment and tourism development." The information obtained so far indicates that inappropriate management of wastewater and solid waste would result in serious groundwater contamination and destruction of the coastal environment due to the peculiar geological characteristic－karstic formation－ of Yucatan Peninsula. The Master Plan aims at prevention of the water contamination and destruction of the environment, which may cause serious damage to tourism, to the rich biodiversity, to the unique water resource and to the human health in the Study Area. These are assumed as benefits to be brought about by the implementation of the Master Plan.

For analytical purposes in this economic evaluation, incremental cost is assumed as the cost needed to bring about the benefits. The incremental cost is the difference between the cost required to implement the Master Plan and the cost required to continue the current Wastewater Management and Solid Waste Management systems (without the Master Plan).

The economic evaluation basically tries to make a comparison between the benefit and the cost of the Master Plan.

b. Cost

The table below shows the incremental cost of the Master Plan amounting to 3,304 Million Pesos for Wastewater Management and 441 Million Pesos for Solid Waste Management, for a total of 3,745 Million Pesos for the Master Plan.

Table 9-52: Incremental Cost of the M/P

Unit: million pesos

Year	Wastewater management	Solid waste management	Total
2004	175	14	189
2005	481	32	513
2006	120	29	149
2007	529	37	566
2008	274	35	309
2009	414	31	445
2010	290	33	323
2011	206	51	257
2012	196	49	245
2013	187	42	229
2014	211	44	255
2015	221	44	265
Total	3,304	441	3,745

c. Benefit

The Master Plan aims ***to preserve the groundwater and the coastal aquatic environment in the Study Area*** by protecting them from inappropriate management of wastewater and solid waste, and is expected to bring about the following benefits:

1) ***Keeping of attractions to tourists:*** *to avoid negative impact on tourism due to environmental degradation*

2) ***Preservation of biodiversity:*** *to avoid loss of resources that could be utilized for foods and/or medicine in the future*

3) ***Protection of the water source for drinking water:*** *to avoid the cost of treatment of contaminated groundwater, and to prevent disease outbreaks*

Prosperity by tourism development cannot be achieved once the image of the concerned place is damaged[1]. Contamination by wastewater and solid waste has been recently emphasized as one of the major threats to coastal environment, in addition to direct threats such as overexploitation of beaches. Seawater contamination by wastewater in Acapulco, which is one of the famous resorts in Mexico, has been reported and damaged its image recently. In 1990 the numbers of tourists to Acapulco and Cancun were almost the same, standing at about 1.5 million. However, there was a large difference between them in 2001, about 3 million in Cancun and about 2.2 million in Acapulco. Several factors can be considered as possible causes of the difference, such as tourist resources, abnormal weather, etc. Contamination of the coastal area caused by inappropriate management of wastewater and solid waste is also considered an important factor among them. In Mexico, a decrease in the number of tourists seriously damages both the regional and national economies. In 2000, the tourism sector occupied 8.4% of Gross National Product (GNP), 5.5% of employees over the country and the third position as earner of foreign currency amounting to 8,295 Million Dollars[2]. Quintana Roo is one of the important States in regard to tourism. It is estimated that the State earns one-third of the income. As just described, the tourism is important to both the regional and national economies. Hence, the benefit to be derived from tourism is quantitatively evaluated here.

Mexico has a rich biodiversity due to the great variety of ecosystems in the country. The number of species of mammals is the top and the one of reptiles is the second in the world. And a great number of plants and animals are endemic species to Mexico. In Quintana Roo State where the Study Area is located in, 669 species of animals and about 1500 species of

[1] Guidelines for Integral Management of Coastal and Marine Areas, UNEP, 1995
[2] SECTUR

plants make their habitats, including many endangered species such as green turtles (*Chelonia mydas*), manatees (*Trichechus manatus*) and jaguars (*Panthera onca*) [3]. Biodiversity is a highly valued economic resource all over the world, e.g., as potential sources of foods and medicine in the future. An indication of its value consists of the ratification of the treaty of "Conservation on Biological Diversity" by over 180 countries. However, an economic method has not been established to quantitatively evaluate the value of biodiversity. This does not mean that the biodiversity is economically unworthy, but only that its quantification requires the establishment of a practical method. Consequently, although the value of the biodiversity in the Study Area is qualitatively highly respected, the Study does not attempt a quantitative analysis.

Protection of water source for drinking water has a beneficial effect on prevention of epidemics. It is reported[4] that the number of intestinal infection cases per 100,000 persons in Yucatan Peninsula is higher than the national average, which in 1999 was 4,955.2, while the State averages were 8,698.3 in Yucatan, 6,005.9 in Campeche and 6,178.9 in Quintana Roo. It is generally accepted that contamination of groundwater would be a main cause; and economic losses caused by sick leaves is significant. It is obvious that the implementation of the Master Plan will protect water sources for drinking water and will contribute to the prevention of epidemics. However, it is hard to quantitatively identify to what degree the Master Plan can lower the morbidity. Accordingly, although the beneficial effect on prevention of intestinal diseases is duly respected, quantitative evaluation is not attempted here.

d. Quantitative Economic Evaluation on Tourism Revenue

It is obvious that a tourism area cannot flourish once its image is damaged, although there has been no theory or empirical proof to explain the correlation between the degree of water contamination/environmental degradation and the decrease in tourism revenue. Quintana Roo has many historic sites of Mayan culture that are attractive to tourists. However, the most important attraction is its coastal area having white sand beaches and turquoise blue water, which is nourished by clear and abundant groundwater. Therefore, it is considered reasonable to estimate that the destruction of the coastal environment caused by the contamination of groundwater and seawater would seriously decrease the tourism revenue.

d.1 Forecast of Tourist Number without the Master Plan

During about ten years between 1990 and 2001, the number of tourists had increased from 1.5 to 3.0 million/year in Cancun, and from 1.5 to 2.2 million/year in Acapulco. This

[3] SEMARNAT

difference of 0.8 million/year between Cancun and Acapulco is considerably large. Comparing the increase rate of tourist number in Acapulco with that of national average and that of Cancun, the rate of 3.7%/year in Acapulco is 1.6%/year lower than the national average of 5.3%/year and 2.3%/year lower than the rate of 6.0%/year in Cancun.

It makes no sense at all to assume that only water contamination and the resulting negative image had lowered the increase rate of tourists in Acapulco. Therefore, the economic evaluation of this Study conservatively estimates the adverse effects of water contamination/environmental degradation on the tourism in the case "without the Master Plan", by defining the adverse effect as 1%/year decrease with respect to the forecasted increase rate after 2006, then 10% decrease in 2015.

Table 9-53: Number of Tourists (1990-2001)

Unit: 1,000 persons

Year	Cancun	Acapulco	Mexico
1990	1,566	1,466	22,260
1991	1,904	1,581	22,403
1992	2,036	1,784	22,188
1993	1,974	1,902	21,976
1994	1,958	1,930	22,077
1995	2,155	1,782	27,483
1996	2,306	1,914	29,460
1997	2,640	1,860	31,456
1998	2,652	1,899	33,164
1999	2,819	4,226	41,948
2000	3,043	2,178	40,782
2001	2,986	2,197	39,091

Source: Anuario Estadistico de los Estados Unidos Mexicanos EDICION 2002, INEGI

Table 9-54: Growth Rate of Number of Tourists (1990-2001)

Year	Cancun	Acapulco	Mexico
1990	100.0%	100.0%	100.0%
1991	121.6%	107.8%	100.6%
1992	130.0%	121.7%	99.7%
1993	126.1%	129.7%	98.7%
1994	125.0%	131.7%	99.2%
1995	137.6%	121.6%	123.5%
1996	147.3%	130.6%	132.3%
1997	168.6%	126.9%	141.3%
1998	169.3%	129.5%	149.0%
1999	180.0%	288.3%	188.4%
2000	194.3%	148.6%	183.2%
2001	190.7%	149.9%	175.6%

[4] Impacto delas enfermedades diarreicas agudas en la Península de Yucatán

Table 9-55: Annual Growth Rate of Number of Tourists (1990-2001)

Year	Cancun	Acapulco	Mexico
1991	21.6%	7.8%	0.6%
1992	6.9%	12.8%	-1.0%
1993	-3.0%	6.6%	-1.0%
1994	-0.8%	1.5%	0.5%
1995	10.1%	-7.7%	24.5%
1996	7.0%	7.4%	7.2%
1997	14.5%	-2.8%	6.8%
1998	0.5%	2.1%	5.4%
1999	6.3%	122.5%	26.5%
2000	7.9%	-48.5%	-2.8%
2001	-1.9%	0.9%	-4.1%
Average	6.0%	3.7%	5.3%

d.2 Forecasts of Tourist Number and Tourism Revenue

Forecast of tourist number is available in a development plan of Quintana Roo State[5]. Also, tourism revenue per tourist was estimated as USD604 in 2000 according to the same plan. In the case "with Master Plan", it is supposed that a decrease in the number of tourists caused by water contamination would not occur, as a deterioration of groundwater quality is not anticipated. In the case "without Master Plan", it is supposed that the number of tourists would decrease by 1%/year with respect to the forecasted growth rates starting in 2006, as discussed above. The Table below shows the result of calculation.

Table 9-56: Forecasts of Tourist Number and Tourist Revenue

Year	No. of tourists		Revenue (million pesos)	
	w/ the M/P	w/o the M/P	w/ the M/P	w/o the M/P
2004	1,945,788	1,945,788	12,928	12,928
2005	2,156,471	2,156,471	14,328	14,328
2006	2,275,250	2,252,498	15,117	14,966
2007	2,387,939	2,340,180	15,865	15,548
2008	2,495,671	2,420,801	16,581	16,084
2009	2,599,220	2,495,251	17,269	16,578
2010	2,699,138	2,564,181	17,933	17,036
2011	2,795,833	2,628,083	18,576	17,461
2012	2,889,614	2,687,341	19,199	17,855
2013	2,980,722	2,742,264	19,804	18,220
2014	3,069,348	2,793,107	20,393	18,557
2015	3,155,645	2,840,081	20,966	18,869
Total	31,450,639	29,866,045	208,959	198,430

d.3 Benefit

The difference in revenues between the cases "with Master Plan" and "without Master Plan" is considered as the benefit. As the table below shows, the cumulative benefit by 2015 is calculated as 10,529 Million Pesos.

Table 9-57: Benefit of the Master Plan

Unit: million pesos

Year	Revenue		Benefit (balance)
	w/ the M/P	w/o the M/P	
2004	12,928	12,928	0
2005	14,328	14,328	0
2006	15,117	14,966	151
2007	15,865	15,548	317
2008	16,581	16,084	497
2009	17,269	16,578	691
2010	17,933	17,036	897
2011	18,576	17,461	1,115
2012	19,199	17,855	1,344
2013	19,804	18,220	1,584
2014	20,393	18,557	1,836
2015	20,966	18,869	2,097
Total	208,959	198,430	10,529

d.4 Evaluation

Net Present Value (NPV), Benefit Cost Ratio (B/C), and Internal Rate of Return (IRR) were calculated from the streams of Costs and Benefits. Results were, as shown in the Table below, NPV = 2,545 Million Pesos, B/C ratio = 2.06, IRR = 39.00%.

Table 9-58: NPV, B/C Ratio, and IRR of the Master Plan (decreasing rate: 1.0% per year from the forecasted rates)

Unit: million pesos

Year	Benefit	Cost	Balance	Discount rate=10%		
				Benefit	Cost	Cash flow
2004	0	189	-189	0	189	-189
2005	0	513	-513	0	466	-655
2006	151	149	2	125	123	-653
2007	317	566	-249	238	425	-840
2008	497	309	188	339	211	-712
2009	691	445	246	429	276	-559
2010	897	323	574	506	182	-235
2011	1,115	257	858	572	132	205
2012	1,344	245	1,099	627	114	718
2013	1,584	229	1,355	672	97	1,293
2014	1,836	255	1,581	708	98	1,903
2015	2,097	265	1,832	735	93	2,545
Total	10,529	3,745	6,784	4,951	2,406	
					NPV=	2,545
					B/C=	2.06
					IRR=	39.00%

[5] Programa Estatal de Desarrollo del Estado de Quintana Roo (PEDU)

d.5 Sensitivity Analysis

Two cases were set for sensitivity analysis, 0.5%/year decrease (Case 1) and 1.5%/year decrease (Case 3) from the forecasted increase rate of tourists after 2006. Table 9-59 and Figure 9-6 show the number of tourists every year in Case 1 and Case 3, together with Case 2 (1%/year decrease) that was previously analyzed. Results of the sensitivity analysis were NPV = 68 Million Pesos, B/C = 1.03 and IRR = 10.87% in Case 1; NPV = 5,020 Million Pesos, B/C = 3.09, and IRR = 50.68% in Case 3.

Table 9-59: Cases of Sensitivity Analysis

Unit: number of tourist

Year	w/ the M/P	Case 1 (-0.5%)	Case 2 (-1.0%)	Case 3 (-1.5%)
2004	1,945,788	1,945,788	1,945,788	1,945,788
2005	2,156,471	2,156,471	2,156,471	2,156,471
2006	2,275,250	2,263,874	2,252,498	2,241,121
2007	2,387,939	2,364,060	2,340,180	2,316,301
2008	2,495,671	2,458,236	2,420,801	2,383,366
2009	2,599,220	2,547,236	2,495,251	2,443,267
2010	2,699,138	2,631,660	2,564,181	2,496,703
2011	2,795,833	2,711,958	2,628,083	2,544,208
2012	2,889,614	2,788,478	2,687,341	2,586,205
2013	2,980,722	2,861,493	2,742,264	2,623,035
2014	3,069,348	2,931,227	2,793,107	2,654,986
2015	3,155,645	2,997,863	2,840,081	2,682,298

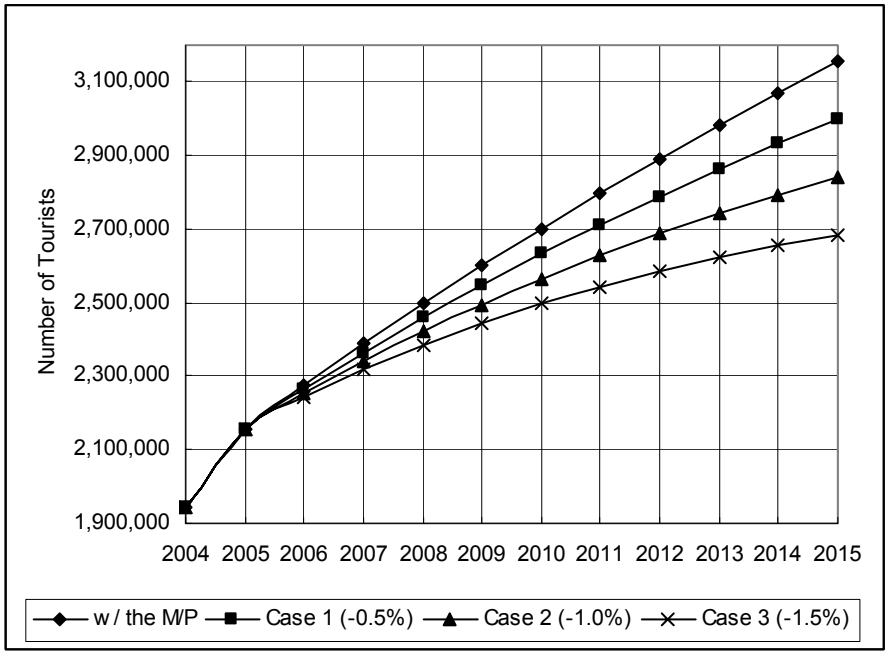


Figure 9-6: Cases of Sensitivity Analysis

Table 9-60: Sensitivity Analysis at Decreasing Rate of 0.5% per year

Unit: million pesos

Year	Benefit	Cost	Balance	Discount rate=10%		
				Benefit	Cost	Cash flow
2004	0	189	-189	0	189	-189
2005	0	513	-513	0	466	-655
2006	76	149	-73	63	123	-715
2007	158	566	-408	119	425	-1,021
2008	248	309	-61	169	211	-1,063
2009	345	445	-100	214	276	-1,125
2010	448	323	125	253	182	-1,054
2011	558	257	301	286	132	-900
2012	672	245	427	313	114	-701
2013	792	229	563	336	97	-462
2014	918	255	663	354	98	-206
2015	1,048	265	783	367	93	68
Total	5,263	3,745	1,518	2,474	2,406	
					NPV=	68
					B/C=	1.03
					IRR=	10.87%

Table 9-61: Sensitivity Analysis at Decreasing Rate of 1.5% per year

Unit: million pesos

Year	Benefit	Cost	Balance	Discount rate=10%		
				Benefit	Cost	Cash flow
2004	0	189	-189	0	189	-189
2005	0	513	-513	0	466	-655
2006	227	149	78	188	123	-590
2007	475	566	-91	357	425	-658
2008	746	309	437	510	211	-359
2009	1,036	445	591	643	276	8
2010	1,345	323	1,022	759	182	585
2011	1,672	257	1,415	858	132	1,311
2012	2,016	245	1,771	940	114	2,137
2013	2,377	229	2,148	1,008	97	3,048
2014	2,753	255	2,498	1,061	98	4,011
2015	3,145	265	2,880	1,102	93	5,020
Total	15,792	3,745	12,047	7,426	2,406	
					NPV=	5,020
					B/C=	3.09
					IRR=	50.68%

Table 9-62: Summary of Sensitivity Analysis

Item	Case 1(-0.5%)	Case 2 (-1.0%)	Case 3 (-1.5%)
NPV (million pesos)	68	2,545	5,020
B/C	1.03	2.06	3.09
IRR	10.87%	39.00%	50.68%

e. Conclusion

It should be recognized that the Master Plan is a set of preventive measures to avoid destruction of the groundwater and the coastal aquatic environment. Once those are devastated, economic loss is enormous, recovery is very difficult and expensive, and complete recovery is impossible, as indicated by many historic cases such as the Love Canal in USA.

Preservation of the groundwater and the coastal aquatic environment aimed at by the Master Plan is expected to bring about three benefits, which are summarized in the Table below. Quantitative analysis of the benefits from tourism was conducted supposing that without the Master Plan the increase rate of tourist number would decrease by 1%/year from the forecasted rate after 2006. Although the decrease rate is arguable, the analysis illustrated that a small decrease in the growth rate of tourist number would result in large economic damages as the sensitivity analysis showed. In other words, the tourism revenue is considerably larger than the cost of the Master Plan.

As discussed above, the Master Plan is to prevent economic losses with respect to tourism, biodiversity and human health, which are likely to bring about benefits that are considered as significantly larger than the cost of the M/P. Accordingly, the M/P is evaluated as economically feasible.

Table 9-63: Summary of Economic Evaluation of the Master Plan

No.	Benefit	Evaluation
1	**Keeping of attractions to tourists:** to avoid negative impact on tourism due to environmental degradation	The tourism in the Study Area is important not only for the regional economy but also for the national economy. The M/P tries to avoid negative image caused by environmental degradation. Quantitative economic evaluation resulted in NPV=2,545 Million Pesos, B/C=2.06, IRR=39.00%
2	**Preservation of biodiversity:** to avoid loss of resources that could be utilized for foods and/or medicine in the future	The Study Area encompasses a unique aquatic environment and valuable ecosystems where rich biodiversity is found. The M/P contributes to preserve this biodiversity.
3	**Protection of the water source for drinking water:** to avoid added treatment cost of contaminated groundwater, and to prevent disease outbreaks	The number of intestinal infection cases caused by contamination of drinking water is higher in Yucatan Peninsula than the national average. The economic loss caused by this intestinal sickness absenteeism is significant. The M/P contributes to avoid this loss.

9.4.2 Financial Evaluation

a. The Wastewater Management Master Plan

The Wastewater Master Plan is financially viable under the assumed conditions, but needs to be implemented as a whole plan, because if the implementation is to be carried out by each municipality, Othon P. Blanco and Felipe Carrillo Puerto would not be financially able to do so. Fortunately, CAPA is a State-Municipal entity and would be able to implement such a plan that may show financial difficulties on a municipality basis but is financially viable as a whole. Then, the income surplus estimated to occur in Solidaridad can be applied to cover the income shortfall in OPB and FCP in order to make the whole Wastewater Master Plan financially viable. It should be noted that the financial evaluation was based on water consumption for daily domestic use, without consideration of industrial or commercial uses.

Although the estimated income from wastewater user charges alone may be barely enough to implement the Wastewater Master Plan, the sensitivity analysis showed the significant effects of changing conditions affecting cost and income. Above all, its financial viability depends on users paying the assumed wastewater service charges according to the assumed expansion of wastewater treatment. Since this is an uncertain factor, it is safer to consider additional income sources. Suggested income sources were one internal to CAPA, the possible surplus of income from water supply, and one external to CAPA consisting of the share of the tour industry in the cost of the Wastewater Master Plan. The contribution of the tour industry, or the participation of the private sector, may be considered as reasonable, since the tour industry is the group that will benefit the most from the preservation of the coastal aquatic environment. Other sources, possibly subsidies from higher levels of government should be considered according to the experience of CAPA in the implementation of prior projects.

b. The Solid Waste Management Master Plan

The Solid Waste Master Plan in the Study Area can be financially viable depending on some hard decisions. These administrative/management decisions refer to imposing user charges on all waste generators, the level of these user charges, and the bill collection efficiency. The indicative user charges to achieve financial viability and self-sufficiency were 50 Pesos per month for households and 200 Pesos per month for business firms, provided business firms comprise 15% of the number of households, and bill collection efficiency reach 90% by 2009. Under these conditions, FIRR for the Master Plan as a whole would be around 18%.

The same conditions would make the Solid Waste Master Plan financially viable and self-sufficient in two of the three Municipalities, as indicated by FIRR of 18% in Othon P. Blanco and 11% in Solidaridad. In the case of Felipe Carrillo Puerto, under less demanding conditions consisting of user charges of 40 Pesos per month for households and 100 Pesos per

month for business firms, again assuming business firms to comprise 15% of the number of households and bill collection efficiency of 90% by 2009, the FIRR would be around 11%.

Results from the Model Projects are expected to contribute to the financial viability and self-sufficiency of the Solid Waste Master Plan. The improved operation efficiency, the routine calculation and control of the service costs, and the change in attitude to focus the service provision on income and expenditures specific to the service are expected to contribute to the financial viability of the Master Plan.

Needless to say, if the hard decisions cannot be made and financial self-sufficiency is not pursued, the required funds must be obtained from other sources. Then, the question arises concerning the possible difficulties in procuring the necessary funds, which would be increasing year after year.

9.4.3 Environmental Sanitation Evaluation

The Master Plan aims to preserve the groundwater and the coastal aquatic environment in the Study Area through appropriate management of wastewater and solid waste. In concrete terms, it proposes to control the quality of groundwater at 1.0 mg/litter or less of BOD concentration through reduction of contaminants from wastewater and solid waste. This value has been adopted in Japan as an environmental standard in order to preserve a water body for natural environment and as drinking water source that only requires simple purification. Therefore, it can be said that the value is appropriate taking into consideration of the status of water usage and the rich coastal aquatic environment in the Study Area.

The groundwater is the exclusive drinking water source in the Study Area and it nurtures the rich coastal aquatic environment that forms a part of the second biggest coral reef, Mesoamerica Coral Reef. Therefore, to preserve the groundwater leads to protect health of residents and some millions of tourists and the coastal aquatic environment.

Environmental sanitation in large and densely populated cities can be easily deteriorated, and its impact on the human health and the environment is serious. Meanwhile, environmental impact caused in small cities is relatively small and it can be assimilated in the environment. Furthermore, although infrastructures of the wastewater management and the solid waste management require a large amount of investment, unit investment will bring a larger benefit in large cities due to the scale of the economy. Consequently, it is appropriate that the Master Plan prioritizes measures in large cities.

It is needles to say that efforts by the public administrations which provide services are significant to protect the environmental sanitation, but also actions by the citizens who receive the services are indispensable in order to obtain expected outcomes, e.g., to bear cost

for connection of domestic sewer pipes and to cooperate in waste minimization. In order to induce such actions, the residents, the tourists and the business firms should be aware on the environment protection through appropriate environmental education. In the Study, the Environmental Education Model Project was carried out under coordination of organizations concerned. Such coordination will give the Mater Plan sustainability and expansibility.

The Master Plan focuses on reduction of contaminants originated from wastewater and solid waste. Although these two are principle pollution sources as industries have not been developed in the Study Area, other pollution sources may arise in the future such as storm water discharge in the urban area. In order to overlook if the proposed measures of the Master Plan are appropriately carries out, if those measures effectively work or if there are other serious problems than wastewater and solid waste, it is expected to establish a monitoring system on the groundwater and the coastal water.

9.4.4 Technical Evaluation

a. The Wastewater Management Master Plan

The Wastewater Management Master Plan proposes different level of treatment depending on population size of communities taking into account amount of pollution generation and assimilation capacity of the environment.

High level of treatment system which is proposed for a larger city in the Master Plan has been operated in Playa del Carmen and Chetumal in the Study Area. CAPA and other institutions concerned have acquired technologies that are necessary for its planning, designing, construction, operation and maintenance. It is expected that those technologies will be improved through implementation of the Master Plan.

Meanwhile, CAPA constructed new treatment facilities in three small cities and, as of July 2004, final preparation works for operation were carried out. Construction of the facilities was the first experience for CAPA, thus, various technical problems had arisen. However, those problems had been overcome with efforts by CAPA and advices by the Study Team. The experience obtained here will make the implementation of the Master Plan viable.

One of major problems in the sector of wastewater management is lack of number of connected houses to the sewer system as the residents hate to bear the connection cost, e.g., the treatment plant in Chetumal receives wastewater that is only 15% of the capacity of the plant. In the Village Type Wastewater Model Project carried out during the Study, meetings with local residents were held with environmental education activities and a fund for reducing financial burden was established in order to promote connection to the sewer system, then, those measures were successful. Those measures will be applicable in other

areas, not only in areas which will have new systems but also in areas which have existing systems. Then, it will work to increase the sewer coverage as proposed in the Master Plan.

b. Solid Waste Management Master Plan

The Solid Waste Management Master Plan also proposes higher level of a SWM system for a larger city and simpler system for smaller city taking into account distribution of population and population size of respective community in the Study Area. The Master Plan has following three objectives inherent to SWM, i.e., 1) provision of sanitary living environment through improvement of waste collection works, 2) mitigation of environmental impact through proper waste disposal, and 3) contribution to resource conservation through waste minimization measures.

Waste collection coverage is set between 80 and 100% depending on population sizes of communities taking into account different degree of their demands for waste collection service. In order to raise the collection coverage, it is preferable to make the existing collection works efficient, then, to expand collection area with excess capacity. The Collection Improvement Model Project carried out in Felipe C Puerto actually improved the collection coverage from 50% up to 90%. Viability and effectiveness of the measures proposed in the Model Project were proved and the municipal personnel concerned acquired knowledge and technique to carry out the measures. Then, it can be said that the implementation of the Master Plan has begun and the municipalities are ready to continue it.

Regarding waste disposal, four levels of technical measures depending on population size of community have been proposed. The first three levels are improvement of existing disposal sites. The fourth level proposes construction of sanitary landfill which has leachate collection and treatment system. The Improvement of the Existing Disposal Site Model Project in Othon P Blanco upgraded the open dump site to the level three which has a landfill with gas removal facility. In results, proper landfilling such as waste compaction and soil cover has been practiced and generation of leachate that is a main pollution source of groundwater has been reduced to a large degree. Furthermore, introduction of the weighbridge has made it possible to know waste amount brought in the site, then, it allows the municipality to plan the operation. Knowledge and skills acquired through the Model Project will serve a foundation for realizing the suspended new sanitary landfill project.

Activities related to waste minimization were found in the Study Area beforetime, however, those were not strategic approach such as recycling by the informal sector and sporadic events concerning to environmental education conducted by organizations concerned. The Master Plan proposes environmental education and recycling activities in schools and communities. A part of the proposal has been conducted in the Environmental Education

Model Project where an environmental education method was transferred to the Mexican counterpart and teachers, and environmental education classes subsequently were held in some schools using education materials provided by JICA under coordination of organizations concerned. Therefore, it can be said the proposed measures listed in the Master Plan has begun and the organizations and persons concerned have acquired capacity to continue and develop the measures.

9.4.5 Institutional Evaluation

The State of Quintana Roo has legal and administrative frameworks which promote and regulate all activities related to the implementation of the Master Plan.

On a federal level, legislation concerning the management of solid waste has been complemented with the enforcement of the "General Law for the Prevention and Integral Management of Waste". Subsidiarily, with the approval of the "Regulation for the Rendering of the Public Service for the Integral Management of Urban Solid Waste", the municipalities will have a regulatory framework for the rendering of the services.

The management of wastewater is regulated on a federal level through the "Law of National Waters" and the "Federal Law for the Rights as Regards of Water"; the former law is in process of modification.

On a state level, CAPA is regulated through the "Law of Drinkable Water and Sewer System of the State of Quintana Roo", which in its article 36 states that the owners or proprietors of improved real estate and, business, industrial and other type of properties that by their nature are obliged to the use of drinkable water, **are also obliged to the connection to the sewer system in places where this service exists, within the fixed terms.**

The normative exists but unfortunately this is not executed. That is the case of the intra household connections that should connect to the sewerage system in order to protect the aquifer from free discharges to the septic tanks. A new effort to promote the connections is being carried out in the community of Subteniente López with funds of JICA.

The information and coordination among the three government levels should be fluid and of routine with the purpose of gaining synergy. The Master Plan has left installed the "Information System for the Integral Management of Waste" (SIGIR), which may be enlarged in order to incorporate other organizations and achievements.

In the M/P there is a document about the creation an Executing Agency of the Master Plan. This agency has as main objective the implementation of the Master Plan and the achievement of the goals proposed; as well as to strengthen and facilitate the coordination

among the three government levels with the purpose of protecting the aquatic environment of the Coast of Quintana Roo.

9.4.6 Overall Evaluation

The proposed Master Plan will preserve the groundwater and the coastal aquatic environment in the Study Area. Contamination and deterioration of those will induce reduction of tourism revenue, increase of medical cost, loss of employment opportunity and loss of biodiversity. Those will be enormous economic losses compared to the cost of the Master Plan, then it can be said that the Master Plan is economically viable.

The Wastewater Management Master Plan is financially viable under the current tariff system of CAPA. However, analyzing the municipalities separately, Othon P Blanco and Felipe C Puerto will fall in financial deficit. The Wastewater Management Master Plan will be financially viable, when considering the three municipalities as a whole.

Solid waste service has not been appropriately charged in the Study Area excluding Solidaridad. The Solid Waste Management Master Plan will be financially feasible if a political decision to charge the beneficiaries for the service is made.

The Master Plan will contribute to protection of health of residents and tourists, as it will preserve the groundwater which is the only drinking water source in the Study Area. And also, the Master Plan will contribute to conserve the worldwide unique ecosystem in a large extent.

CAPA which is in charge of wastewater management in the Study Area has technical capability to implement the Master Plan. Meanwhile, the municipalities which are in charge of solid waste management have acquired knowledge and skills through the Model Projects to carry out the Master Plan. Thus, it can be said the Master Plan is technically viable and it is expected for those organizations to develop their capability through implementation of the Master Plan.

Consequently, it is judged that implementation of the Master Plan is reasonable and viable overall, and it will formulate a foundation for a sustainable development of the Study Area in the future.

Chapter 10

Recommendations on Groundwater Management

10 Recommendations on Groundwater Management

The Study focuses on the sectors of Wastewater Management and Solid Waste Management according to the Scope of Work agreed by the both the Mexican Side and The Japanese side. However, it is understood importance of Groundwater Management that has close relation to the WWM and SWM due to the geologic characteristic of the Study Area. Therefore, this chapter gives general recommendations on the GWM.

10.1 Risk Assessment

The management of groundwater basin implies a program of development and utilization of subsurface water for some stated purpose, usually of a social or economical nature. In general, the desired goal is to obtain the maximum quantity of water to meet predetermined quality requirement at least cost[1].

Considering vulnerable characteristics of aquifers and growing water demand in tourism in the Peninsula of Yucatan, groundwater situation will progressively become critical in the future. Therefore, the management goal of the Study Area must be set up based on the risk assessment which is anticipated at present.

Risk 01

Saltwater intrusion or "*Upconing*" may occur due to overdraft of groundwater.

- According to water balance calculation in Quintana Roo State[2], an approximate 13,350 Mm^3/year of water is estimated to recharge the limestone aquifers. An estimated amount of extraction is 350 Mm^3/year. It occupies only 2.6 % of the recharge. On the other hand, evapo-transpiration and discharge run up 6,300 Mm^3/year (47.2%) and 5,850 Mm^3/year (43.8 %), respectively. Extraction volume seems still very small compared to recharge at present. In addition, increasing volume of extraction may be compensated by decreasing volume of discharge to sea and other area. However, it should be noted that most of pumping wells are concentrated in the coastal urban areas. Considering water balance in the coastal urban area, if groundwater is overdrafted more than recharge, seawater easily intrudes into the aquifer and compensates the recharge. Especially, the aquifer in the Peninsula of Yucatan contains an underlying saltwater layer and groundwater is being pumped by wells penetrating only the upper freshwater layer. A local rise of the

[1] Todd, D.K.(1980): Groundwater Hydrology, Second Edition, John Wiley & Sons

interface between fresh and saltwater layers below the wells occurs when it is excessively pumped[3]. Accordingly, groundwater will be totally deteriorated and water supply will be seriously damaged unless groundwater extraction is controlled.

Risk 02

Groundwater contamination may occur due to wastewater, animal waste, fertilizer pesticides, septic tanks and so on.

- Although saline water is the most common pollutant in fresh groundwater as mentioned above, groundwater contamination may occur by filtration of various pollutants through the vadose zone and/or directly in the aquifer mainly caused by disposal of wastewater. Limestone aquifer generally has wide variety of density, porosity and permeability depending on degree of consolidation and development of permeable zones after deposition. Openings in limestone may range from microscopic original pores to large solution caverns forming subterranean channels sufficiently large to carry water flow. Actually, many large caverns are found in the Peninsula of Yucatan and some of them are utilized for tourist places. Considering such a large pore or cavity and high permeability in the limestone, contaminated groundwater may spread over entire aquifer system very rapidly[4].
- Presently in the Study Area, the coverage rate of sewer system is very low even in urban area. Treated waste water in CAPA sewer system is being injected into saltwater layer underlying the freshwater layer through injection well. Wastewater from service, such as hotels and restaurants, and industry are also injected into saltwater layer. However, it is doubtful whether water is injected after treatment at septic tank or not. Most of wastewater in uncovered area of the sewer system is discharged into sink hole as well as -domestic wastewater in the rural area. There's a high possibility of contamination by animal waste, fertilizer, pesticides and so on in the rural area as well. In addition to the above, waste disposal site may cause another contaminant source since the waste is dumped and covered by soil but no prevention measure is undertaken against seepage.

[2] SECRETARIA DE AGRICULTURA Y RECURSOS HIDRALICOS, COMISION NACIONAL DEL AGUA (1989) :SINOPSIS GEOHIDROLOGICA DEL ESTADO DE QUITANA ROO,
[3] This phenomenon is known as "*Upconing*"
[4] Generally, a contaminant plume from a point source tends to be long and thin when groundwater is moving relatively rapidly. But where the flow rate is low, the pollutant tends to spread more laterally.

10.2 Management Goal

Based on the risk assessment, the goals for groundwater management can be set up as follows.

Goal 1

To control groundwater extraction based on the evaluation of "the perennial yield".

The "perennial yield" of a groundwater basin defines the rate at which water can be withdrawn perennially under specified conditions without producing an undesired result[5]. An undesired result is an adverse situation such as progressive reduction of the water resource, development of uneconomic conditions, degradation of groundwater quality and land subsidence etc. This concept can be applied to the management goal for the limestone aquifers in the Peninsula of Yucatan. As mentioned earlier, groundwater is a sole source for water supply in this area. Saltwater intrusion caused by overdraft is an undesired result and must be avoided. Therefore, strict groundwater extraction control becomes a final goal of the management. Once a "perennial yield" is determined, a permissible groundwater extraction can be allocated for each urban and rural area considering socio-economic constraints. The achievement ratio of control may be obtained through observation of the monitoring wells and record of pumping. However, a comprehensive and basin-wide hydrogeological study is required in the long run in order to achieve this goal.

Goal 2

To protect aquifer from contamination caused by domestic, industrial, agricultural sources and so on.

- Aquifer protection could be achieved ultimately construction of sewer system and containment of pollution source. However, possible protection measures should be undertaken in the process of attainment of such facilities and establishment of proper institutional and legal settings. It is indispensable to establish groundwater monitoring networks in order to observe water quality and water levels in the short and medium term. In addition, existing wells, such as CAPA production wells for municipal water supply, should be regularly monitored from the point of national drinking water standard.

- As the Peninsula of Yucatan is made up of karst topography, no surface water exists except the River Hondo and "*Cenote*". In order to conserve coastal sea water body,

wastewater is injected into underground saltwater layer and this way of disposal may last a long time in the future. Nevertheless, behavior of injected water and its effect on the freshwater layer are not well understood at present. Although the injection well is registered at the CNA, the design of injection well, equipment and facility, injection record etc are not stored in the database. Information on, such as the depth of screen position, detection of saltwater/freshwater interface, acquisition of hydrogeologic parameters, method of sealing in the annular space between bore wall and casing etc are main issues concerning standardization of design and construction of the injection well. Groundwater management must also clearly focus on this issue.

[5] Todd, D.K（1980, aforementioned）

10.3 Improvement Measures

Proposed improvement measures corresponding to the groundwater management goal are shown in the table below.

Table 10-1: Proposed Improvement Measures on Groundwater Management

Strategies		Contents (Proposed Improvement Measures)
Groundwater Management System	Groundwater Database Establishment	Groundwater database, which is necessary for planning, implementation, monitoring and evaluation of groundwater resource, is established and maintained. 1) Collection of existing well data • collection of data from users and drilling companies • construction of well inventory 2) Collection of relevant data and construction of GIS • collection of materials for GIS (natural conditions, land use, population, water supply etc) • construction of GIS system linked with well inventory 3) Establishment of reporting, inspection, analysis and evaluation system using GIS linked groundwater data base • institutional and legal settings • maintenance of the data base (regular updating and modification)
	Construction of Monitoring Network	Groundwater monitoring networks are expanded and monitoring method is improved in order to prevent limestone aquifers from contamination and annual decline of water levels. 1)Automation at existing monitoring wells • examination of well structure, water levels and quality • automation at existing stations • periodical visit and check of equipment 2) Expansion and construction of monitoring network • analysis of existing well data • groundwater leveling in selected existing wells • interpretation of geologic conditions • geophysical survey • drilling of monitoring boreholes (core borings when necessary) • water quality analysis • installation of equipment • establishment of collection and processing methodology of monitoring record • annual publication of monitoring data 3) Evaluation of monitoring data • annual appraisal meeting held at CNA • administrative guidance based on evaluation • field investigations
	Establishment of the Standard on the Injection Well Design, Construction and O&M	A technical standard for design, construction and O&M of the injection well is established in order to prevent fresh water layer from contamination. 1) Examination of existing injection wells and drilling companies • examination of well construction method, structure, injected water quality and rate, record of injection at selected existing wells • examination of drilling companies in terms of equipment ,construction method, materials, experiences 2) Monitoring of water levels and water quality in surrounding areas of injection wells • regular groundwater leveling and water quality analysis • analysis of data 3) Preparation of technical standard • clarification of behavior of injected water in the seawater layer • field investigations and construction test of injection well • establishment of standard design and construction method • establishment of O&M of standard based on the monitoring • administrative and technical guidance by CNA

Part IV

Model Projects

Chapter 11

Outline of Model Projects

11 Outline of Model Projects

a. Roles of Model Project

First, a model project has a role to actually implement an activity listed in a master plan and to evaluate its feasibility.

Second, the model project is the initial stage of implementation of the master plan. It has a role to launch the implementation successfully. An executing agency and organizations concerned can actually see advantageous effects brought by the model project. Then, they can confidently implement the model project and the master plan.

In order to encourage the executing agency to establish ownership for the master plan, it is necessary to spark changes within the agency, because the master plan itself is a reform of the existing system. Generally, the existing system stands against changes. The model project is a good tool to bring changes within the existing system, as they can experience new challenges and can see effects through its implementation.

The model project is not an event to make something. It is a process to achieve a goal. Going through the process, a required system is established and necessary capabilities are obtained for implementing the master plan.

Summarising the above, the following four points can be raised as roles of the model project.

- Evaluate feasibility of activities listed in a master plan
- Launch implementation of the master plan
- Encourage an executing agency to establish ownership for the master plan
- Encourage establishment of a required system and acquisition of necessary capabilities to implement the master plan.

b. Selected Model Projects

The Mexican Counterpart and the Study Team selected some activities listed in the Master Plan. Then, those were carried out during a course of the Study as Model Projects. Titles and locations of the projects' sites are shown below.

No.	Title
1	Urban type wastewater treatment
2	Village type wastewater treatment
3	Establishment of an Integral SWM Information System
4	Capacity building of Executing Agency in OPB
5	Improvement of the exiting disposal site in OPB
6	Improvement of waste collection in OPB
7	Improvement of waste collection in FCP
8	Establishment of SWM in Costa Maya
9	Environmental education and recycling activity

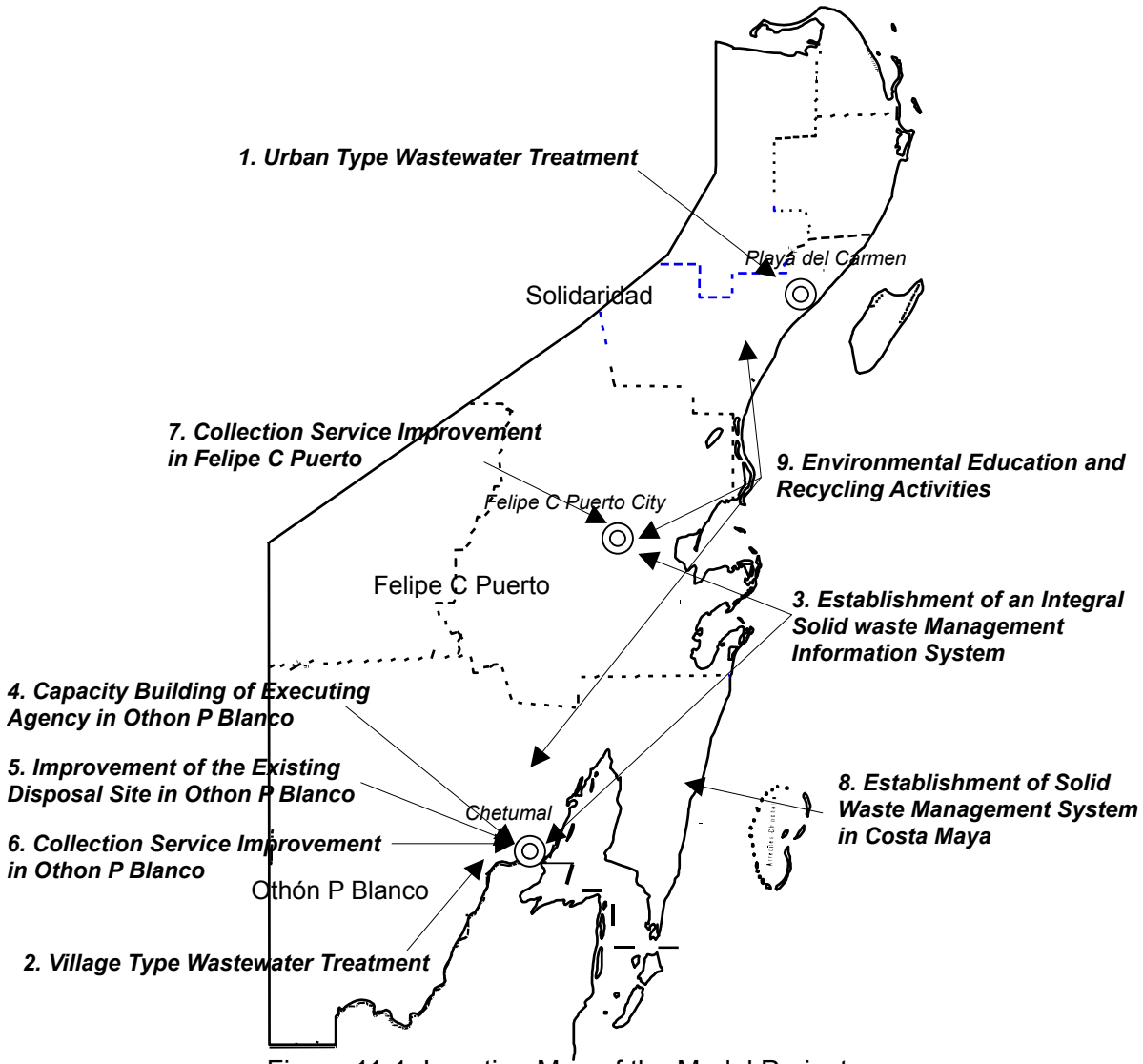


Figure 11-1: Location Map of the Model Projects

c. Schedule of Model Projects

Figure 11-2 shows schedule of the Model Projects. The preparation stage was about two months, where analysis of the present situation and planning of the Mo/Ps were carried out. Also about two months were allowed for the implementation stage, where the Counterparts and the Study Team closely worked and draft manuals were prepared in some Mo/Ps. From March to June 2004, the Mo/Ps were continuously implemented and monitored by the Counterparts themselves according to the prepared manuals. Finally, the Mo/Ps were evaluated based on data obtained from the monitoring in June 2004.

The following is the overall schedule of the Model Projects.

Item	2003			2004						
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul
Preparation	■	■								
Implementation				■	■					
Monitoring						■	■	■		
Evaluation									■	

Figure 11-2: Schedule of Model Projects

Chapter 12

Urban Type Wastewater Treatment

12 Urban Type Waste Water Treatment

12.1 Electromagnetic Survey

12.1.1 Purpose of Survey

A geophysical survey by transient electromagnetic method (TEM) was carried out in Playa Del Carmen. The primary objective of the survey was to determine the composition and distribution of limestone aquifers as well as fresh-saline water interface in the study area.

12.1.2 Outline of the survey

12.1.2.1 Survey Area

TEM survey area was divided into five zones in Playa del Carmen: *a)* urban zone, *b)* actual sewage water treatment plant zone, *c)* new sewage water treatment plant zone (under construction), *d)* municipal landfill zone and *e)* wells battery pipeline zone.

Table 12-1: Survey Area and Number of Stations

LINE	Number of Stations	ZONE
L100	27	Urban zone
L200	23	Urban zone
L300	16	Urban zone
L400	30	Urban zone
L500	25	Urban zone
L600	27	Urban zone
L700	19	Urban zone to New WTP
L800	16	Existing WTP
L900	16	Land fill
L1000	18	Urban zone to Well Fields
Total	217	

12.2 Construction of Monitoring Wells

12.2.1 Drilling Sites

Based on the geophysical survey, the monitoring wells were constructed from the down stream area of CAPA production wells to the coastal town area at different depths in order to confirm lithology of aquifers, distribution of fractures, presence of cavity, fresh water-saltwater interface and water quality.

These wells were constructed at different depths in the places and aquifers as shown in Table 12-2.

Table 12-2: Monitoring Well Construction

Site	Location	Well No.	Aquifers	Depth (m)
Wastewater Treatment Plant	20 38' 16N 87 04' 53W	1'	Upper fresh water	15.0
		2'	Lower fresh water	17.65
		3	Upper salt water	35.0
		4	Lower salt water	100.0
Waste disposal site	20 43' 41N 87 00' 58W	1'	Upper fresh water	15
		2'	Lower fresh water	20.45
Casa Ejidal	20 37' 57N 87 05' 07W	1'	Upper fresh water	15.40
		2'	Lower fresh water	17.35
CAPA Water Supply Reservoir	20 38' 51N 87 03' 52W	1'	Upper fresh water	14.75
		2'	Lower fresh water	17.00

The locations of the monitoring sites are shown in Figure 12-1. After completion of borehole drilling, geophysical loggings were conducted. Dilution test was also conducted to determine the permeability of the aquifer.

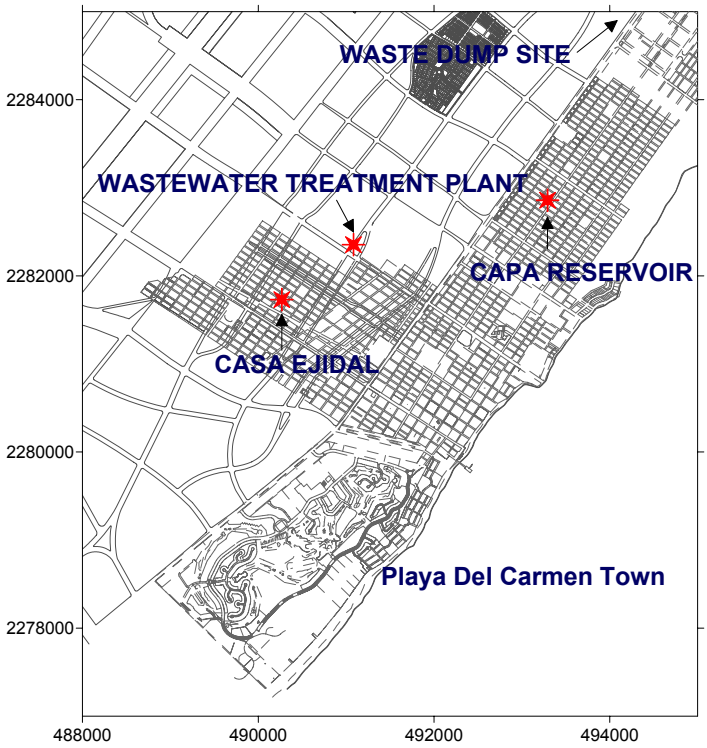


Figure 12-1: Location of Drilling Sites

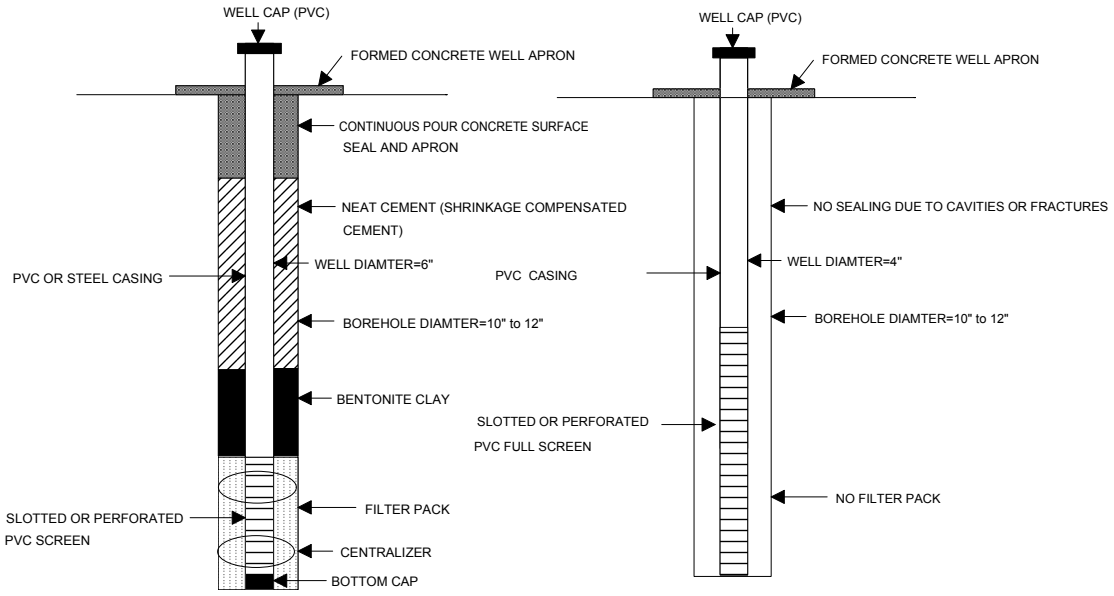


Figure 12-2: Monitoring Well Design

12.2.2 Point Dilution Test

In order to measure groundwater velocities in the limestone aquifers, a point-dilution method (Drost et al, 1968)[1] was applied at the 10 (ten) boreholes.

Three litters of seawater were introduced at 30-50 cm below the water table. After injection, decline or rise of EC was monitored.

Table 12-3: Velocity and Hydraulic Conductivity Estimated from Dilution Test

Site	Well No.	Diameter(cm)	Velocity (cm/sec)	Conductivity (cm/sec)
Wastewater Treatment Plant	1	20.32	0.0040	4.0
	2	20.32	0.0052	5.2
	3	20.32	0.0220	22.0
	4	20.32	0.0206	20.6
Waste disposal site	1	10.0	***	***
	2	10.0	0.0005	0.5
Casa Ejidal	1	25.4	0.0207	20.7
	2	25.4	0.0065	6.5
CAPA Water Supply Reservoir	1	25.4	0.0035	3.5
	2	25.4	0.0011	1.1

*** not analyzed

[1] Point dilution method of investigating groundwater flow by means of radioisotopes, Water Resources Research, v.4, pp. 125-146

12.3 Water Quality Analysis

12.3.1 Purpose

Groundwater quality is very important factor for supplying safe drinking water to the three municipalities of the study area. If groundwater is contaminated, near shore waters may also be affected because it finally flows out the coast through underground aquifers. In the Yucatan Peninsula, the seawater aquifer exists under the fresh water aquifer and the municipal water supply wells are mostly located in the rural inland area some 15 km to 40 km away from the coast. Groundwater of those supply wells is not contaminated yet; however, fresh water aquifer might be contaminated due to disposal of waste water, particularly, in the urban area where the sewer system has not yet fully developed.

12.3.2 Groundwater Sampling and Analysis

Groundwater quality of the newly constructed monitoring wells was collected during a period from February to June 2004 after the completion of the monitoring well construction.

12.3.2.1 Parameters and Sampling in February 2004

a. Parameters

In February 2004, groundwater samples were collected by the study team and these samples were analyzed applying the Mexican Standard of Drinking Water (NOM-127-SSA1-1994). Number of the parameter is thirty seven (37).

b. Sampling

Groundwater samples were collected from the monitoring wells as presented in the following table. In addition to the groundwater, a treated water sample was collected at CAPA Wastewater Treatment Plant in Playa Del Carmen.

Table 12-4: Sampling Location and Date

No.	Location	Name of Well	Well Depth	Sampling Depth	Date
1	Wastewater Treatment Plant	P1	15.0	9.0	28-Feb-04
2	Wastewater Treatment Plant	P2	17.6	16.0	28-Feb-04
3	Wastewater Treatment Plant	P3	35.0	30.0	28-Feb-04
4	Wastewater Treatment Plant	P4	100.0	61.0	28-Feb-04
5	Wastewater Treatment Plant	Treated Water	-	-	28-Feb-04
6	Waste Disposal Site	P1	15.0	8.0	29-Feb-04
7	Waste Disposal Site	P2	20.45	8.0	29-Feb-04
8	CAPA Reservoir	P1	14.7	10.0	29-Feb-04
9	CAPA Reservoir	P2	17.0	16.0	29-Feb-04
10	Casa Ejidal	P1	15.4	10.0	29-Feb-04
11	Casa Ejidal	P2	17.3	16.0	29-Feb-04

12.3.2.2 Parameters and Sampling in the Monitoring Period

Groundwater sampling and analysis were conducted four (4) times by the CNA team monthly from March to June 2004. The following ten (10) parameters were analyzed in the laboratory in Merida: Temperature, pH, Color, Nitrite (NO_2), Nitrate (NO_3), Electric conductivity (EC), Sulfate (SO_4), Total dissolved solids (TDS), General bacteria, Coliform.

12.4 Groundwater Simulation Studies

12.4.1 A Regional Flow Model

In accordance with the purpose of groundwater simulation, various sorts of models can be utilized. Three of them are usually used as 1) 2-D or 3-D regional model; 2) 2-D or 3-D section model; and 3) 3-D detailed model.

The first one, 3-D regional model is usually used to make clear in a comprehensive way the general characteristics of groundwater basin where the study area is located. Therefore, this kind of model is mostly applied as the first step of groundwater simulation, and the regional model covers not only the study area but also its surrounding area.

12.4.1.1 Simulation Result

a. Water Table

The result of the calibration is shown in Figure 12-3.

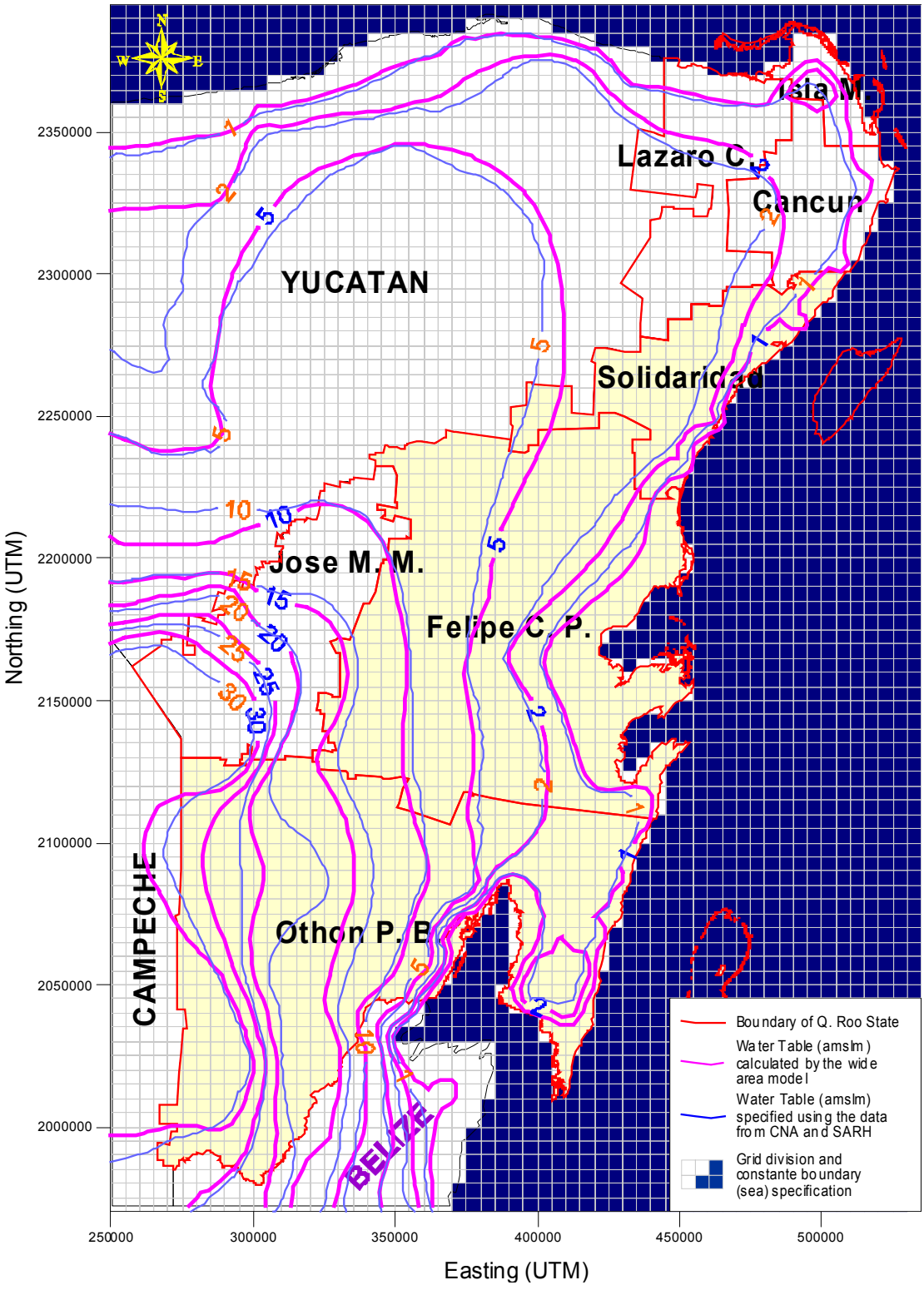


Figure 12-3: Simulated Hydraulic Head

b. Groundwater Flow

Figure 12-4 shows distribution of groundwater flow direction and schematic of the flow velocity in the modeling area.

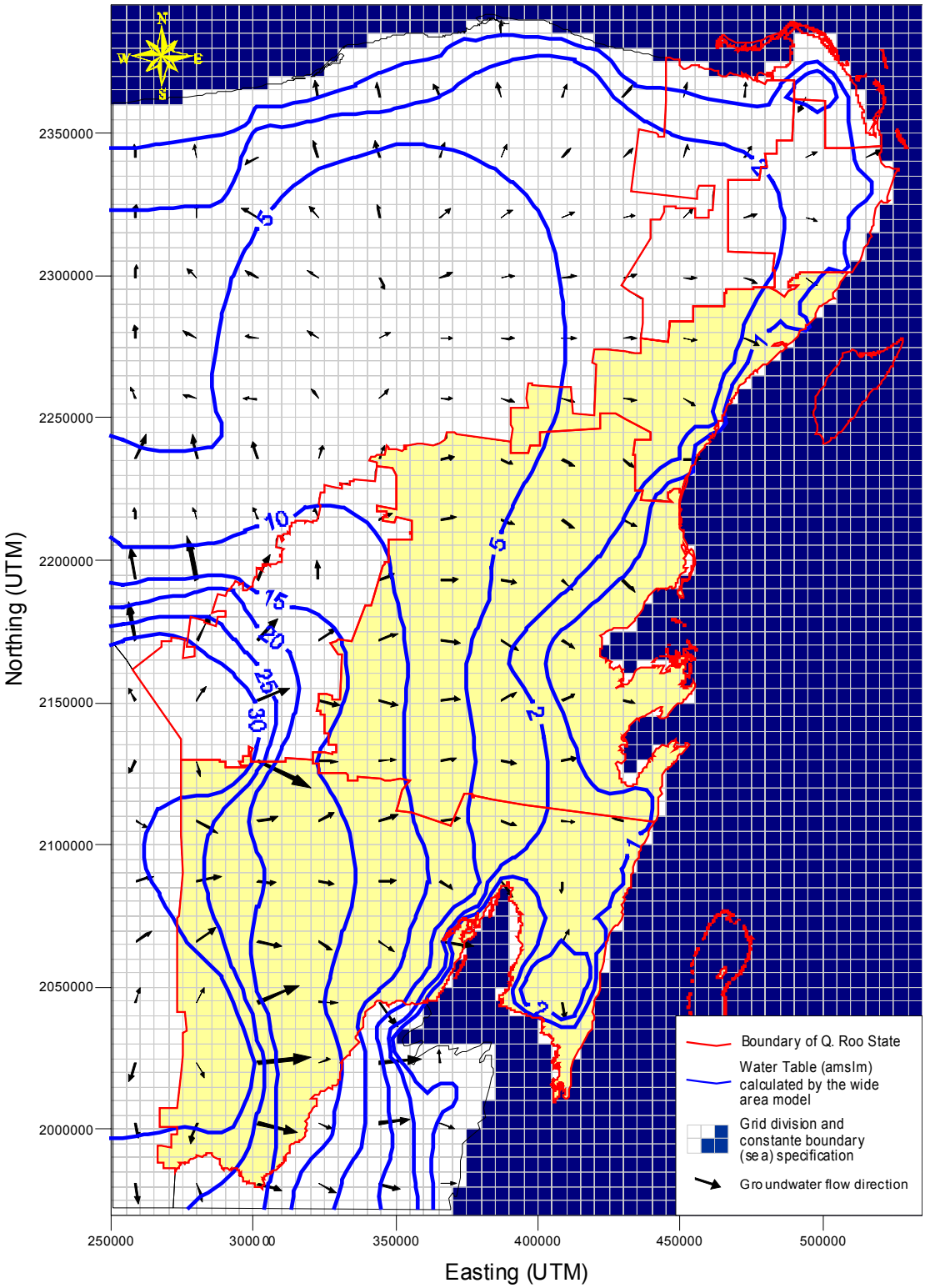


Figure 12-4: Simulated Groundwater Flow Direction and Velocity

c. Water Budget

Table 12-5 shows the water budget the three municipalities in the study area.

Table 12-5: Water Budget of Municipalities in the Study Area

Othon P. Blanco						unit: m3
Recharge	Rain fall	(Flow in)				
		Belize	Campeche	Felipe C.P.	Others(N)	Sub Total
	1,801,261,350	6,635,269	359,936,743	141,590,009	46,452,032	2,355,875,403
Consumption	To sea	(Flow out)	(Extraction)	(Flow out)		
		Belize		Felipe C.P.	Others(N)	Sub Total
	-927,837,776	-811,771,379	-123,977,440	-481,786,978	-10,501,830	-2,355,875,403
Felipe C. Puerto						
Recharge	Recharge	(Flow in)				
		Yucatan	Othon P.B.	Solidaridad	Others(W)	Sub Total
	1,610,991,604	211,264,170	481,786,978	213,610,567	225,206,455	2,742,859,774
Consumption	To sea	(Flow out)	(Extraction)	(Flow out)		
		Yucatan		Solidaridad	Others(W)	Sub Total
	-2,428,581,014	-30,986,790	-21,230,411	-253,959,433	-8,102,127	-2,742,859,774
Solidaridad						
Recharge	Recharge	(Flow in)				
		Yucatan		Felipe C.P.	Others(N)	Sub Total
	345,952,623	124,132,185		253,959,433	384,361,957	1,108,406,197
Consumption	To sea	(Flow out)	(Extraction)	(Flow out)		
		Yucatan		Felipe C.P.	Others(N)	Sub Total
	-862,624,899	0	-29,973,482	-213,610,567	-2,197,249	-1,108,406,197

12.4.1.2 Boundary Between Fresh Water and Sea Water

Groundwater extraction is generally considered safe when extraction amount is less than recharge, and the pumping discharge is much less than recharge in the study area and the whole Quintana Roo State. The checking is especially important in coast area, where vulnerability of aquifer is high because of the high risk of saline (sea water) intrusion.

Figure 12-5 shows the estimated distribution of the boundary between fresh water and sea water. The boundary gets deeper from coast line towards inland. Within a distance of about 10 km form coast line, the boundary might be as high as within -20m (AMSLM). Considering the elevation of ground surface, it could be presumed that wells within the 10km zone along coastal line might penetrate into saline water if the well depth is over 30m.

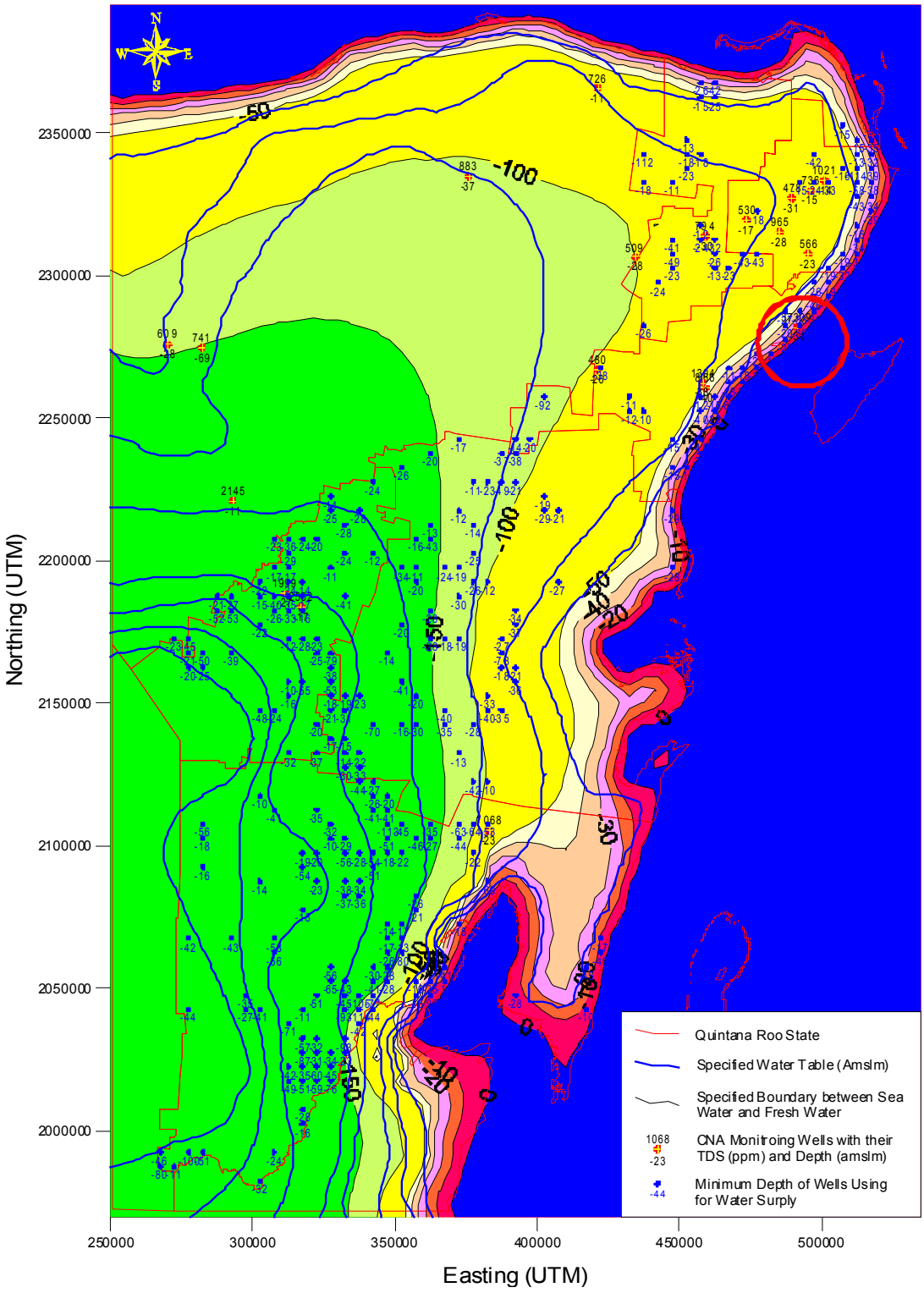


Figure 12-5: Estimated Boundary between Fresh Water and Sea Water

12.4.2 Movement of Injected Water in a Conceptual Model

12.4.2.1 A Conceptual Model

A conceptual groundwater model was developed to understand the movement of injected waste water in the saline aquifer. Solute concentrations in the model are expressed as mg/l of chloride, in which 1 mg/l as fresh water and 100 mg/l as sea water. However, the model does not take density-dependent flow into account in order to simplify the behaviour of the waste water plume.

12.4.2.2 Model Results

The model was used to evaluate the behaviour of the injected waster water plume in the saline aquifer composed of 7^{th} to 14^{th} layers. In this model simulation, effects of hydraulic conductivity value and its vertical to horizontal ratio were evaluated by examining areal and vertical extent of the plume.

a. Effects of horizontal permeability

Areal extent of the injected wastewater plume in 10^{th} layer is shown in Figure 12-6. The plume shows elliptical shape and extends along direction of groundwater flow toward sea. In accordance with increase of the horizontal conductivity, the width of the plume becomes thin in *y*-direction and long in x-direction, and the wastewater spreads in the saline water layer rapidly. In case of low hydraulic conductivity, groundwater is moving relatively slowly and the wastewater tends to spread more laterally to form a wider plume. The plume becomes stable where the wastewater injected into the aquifer at a constant rate as it is counterbalanced with saline water or reaches sea or shallow aquifer and emerges from the underground.

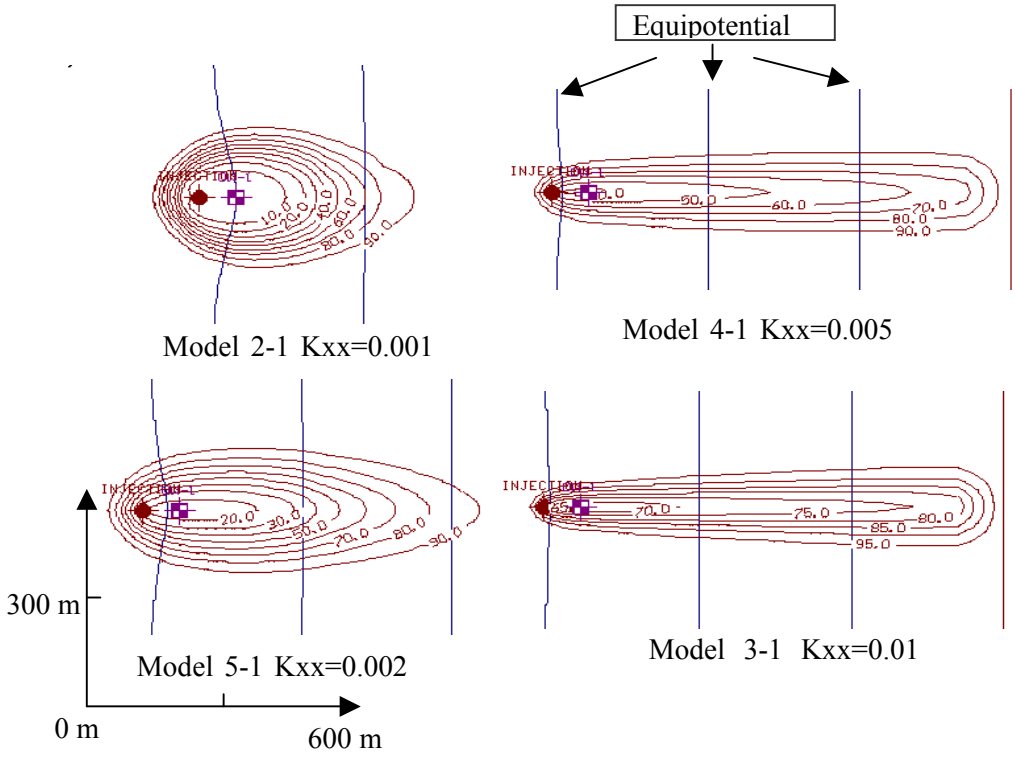


Figure 12-6: Areal Extent of Wastewater Plume in 10th Layer

b. Effects of vertical to horizontal permeability ratio

Figure 12-7 shows the cross sectional view of the plume at different vertical to horizontal conductivity ratio in Model 2. In case of Kzz/Kxx-1/10, the plume becomes thick and flows not only toward sea but shallow aquifers. Saline water is pushed upward and the wastewater emerges from the injected aquifer. In case of Kzz/Kxx=1/20 and 1/40, the plume flows more laterally. However, the transition zone is disturbed since saline water is pushed upward slightly.

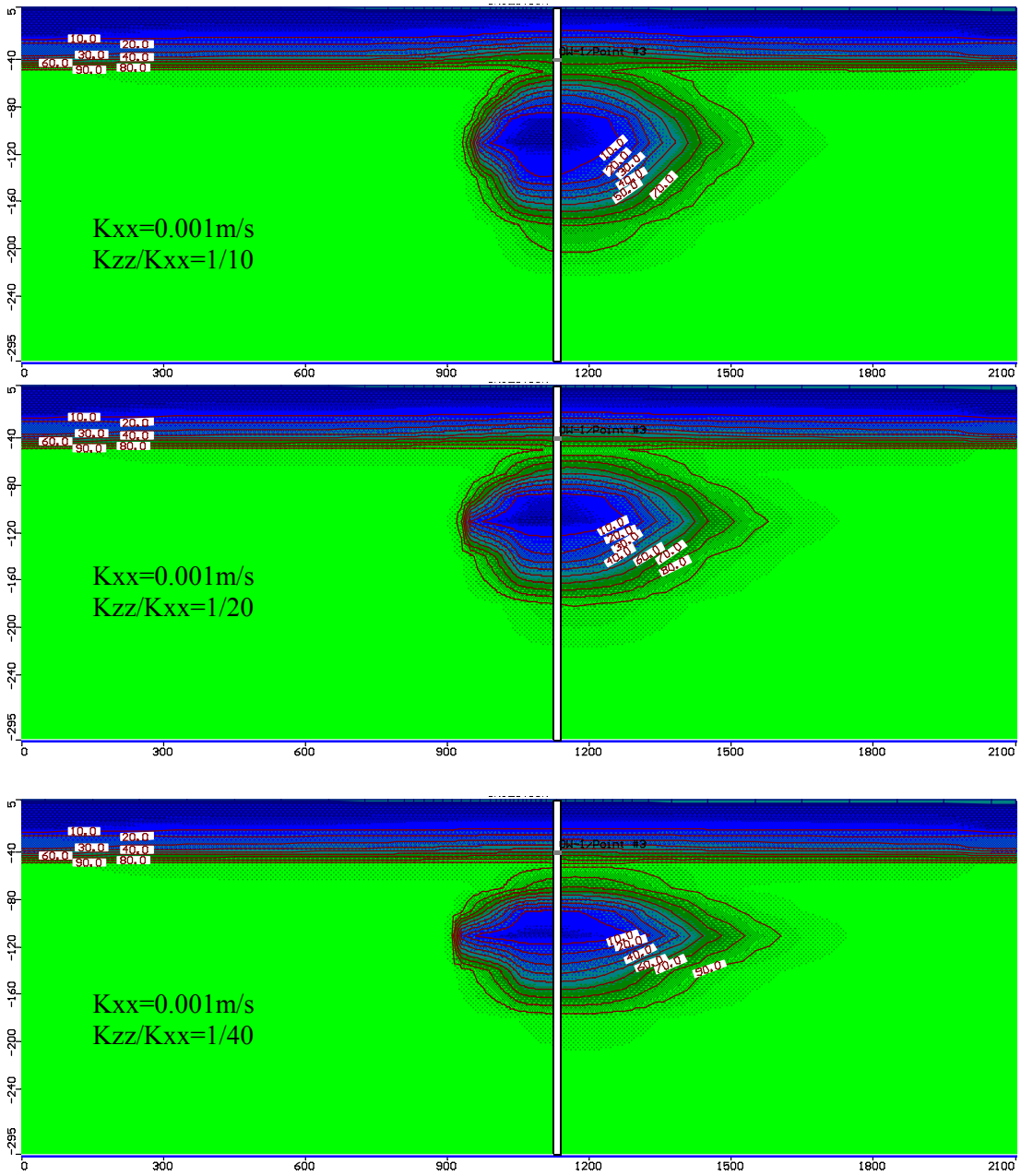


Figure 12-7: Cross Sectional View of the Plume

c. Effects of high permeability layer

Cross sectional and plane view of the plume in the high permeable layer are shown in Figure 12-8**.** The plume becomes planular as the permeability increases. In case of permeability contrast between two layers Kxx1/Kxx2 is 1/10 and Kzz/Kxx=1/40 (lower figure), injected wastewater plume does not go upward and flows laterally toward the sea.

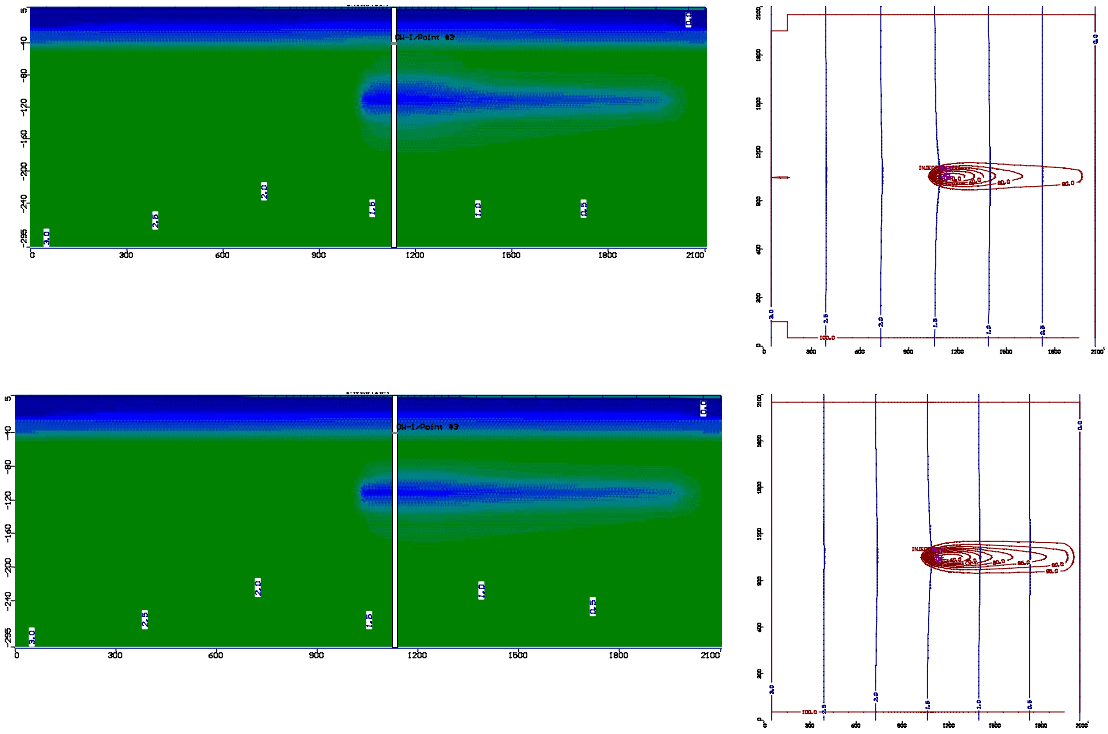


Figure 12-8: Movement of the Plume in the High Permeability Layer

12.4.3 A Density-Dependent Model in Playa Del Carmen

Figure 12-9 shows the results of transport simulation by density dependent model. The upper figure shows a steady state condition of the flow, equi-potential line, the interface between fresh water and saline water and flow direction. As seen in the figure, freshwater flows from the inland to the coast, while the saline water flow from the coast to the inland. In the near shore, saline water flows upward and returns to the coast which is occurred due to density difference in saline and fresh water. In the transition zone, the flow direction is more complicated. The fresh water flows downward while the saline water flows upward.

The thickness of the freshwater is about 50m and 70m at 2.0 km and 4.0 km point from the coast, respectively. This value is rather thicker than the actual value. This is, perhaps, due to the difference of the saline water density imposed in the model and actual density. However, practically, the behaviour of the injected wastewater can be examined by starting from this steady state conditions as initial conditions of the model.

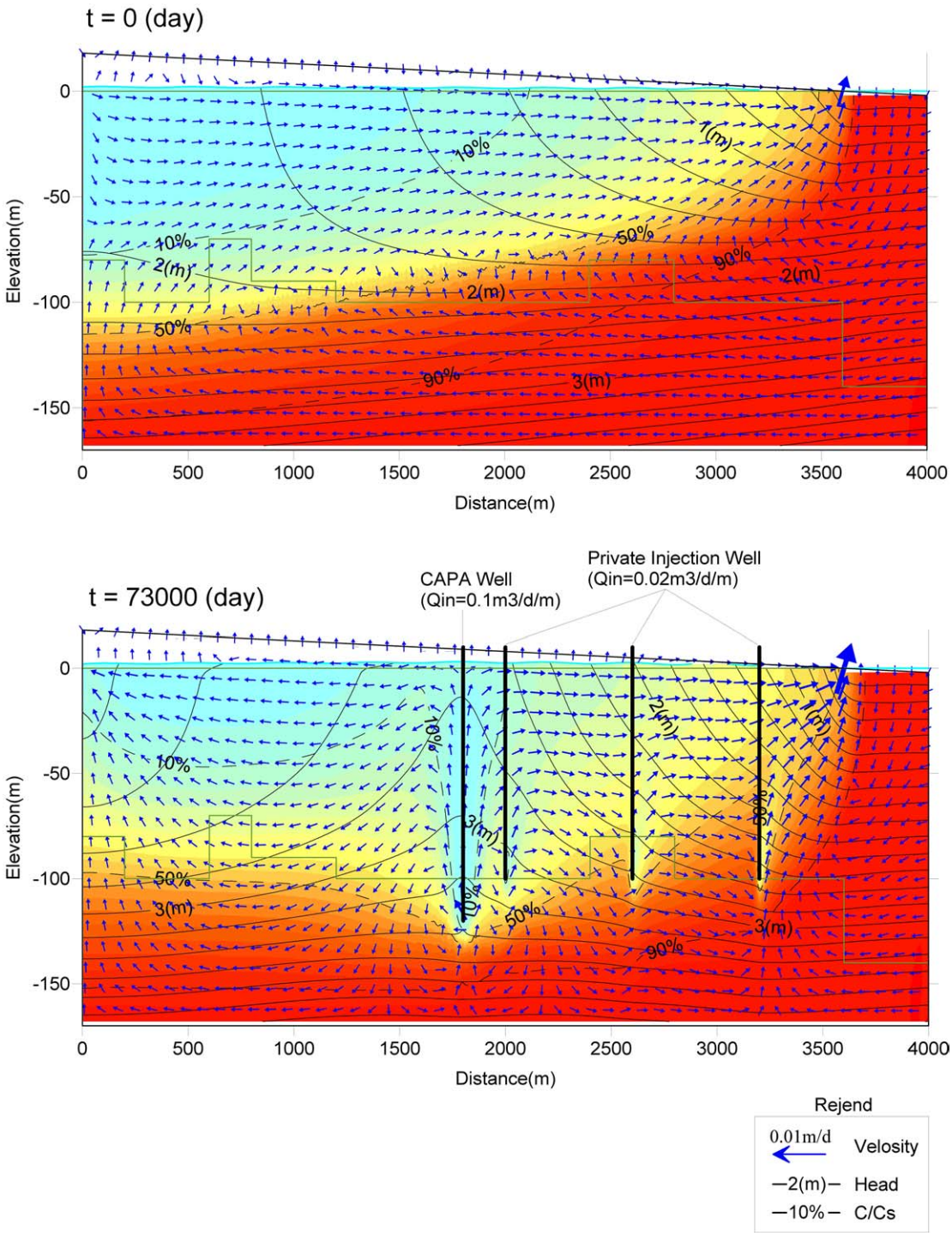


Figure 12-9: Results of Density Dependent Flow Simulation

12.5 Summary and Recommendations

12.5.1 Summary of Hydrogeologic Study

12.5.1.1 Distribution and Characteristics of Limestone Aquifer

1) Underground geology of the study area can be geophysically divided into 3 resistivity layers, i.e. U1, U2 and U3, from the top to the bottom of 200m depth. These resistivity layers are widely distributed in the study area.

2) U1 layer distributes from the ground surface to the depth of 20～25m. This layer is composed of reef limestone and calcareous sandstone. It is abundant in fractures and cavities and becomes a freshwater aquifer indicating 3,000 μS/cm of electric conductivity. Drilling velocity of this layer shows 40 sec/25cm in the fracture zone. It also intercalates hard limestone bed which is showing drilling velocity of 200～400sec/25cm.

3) U2 layer is composed of limestone of abundant fractures and cavities caused by high karst development. The resistivity of the layer is less than 4 Ωm. The fractures and cavities are filled with seawater and the layer composes a seawater aquifer. Electric conductivity ranges from 5,000 to 20,000 μS/cm in the transition zone while it shows more than 40,000 μS/cm in the seawater zone. The thickness of the layer is approximately 50m. The drilling velocity is same as U1 layer. It partly intercalates hard limestone bed.

4) U3 layer is composed of limestone or muddy limestone showing 4～100 Ωm of resistivity. The facies of the low resitivity layer (4～25 Ωm) varies place to place and consists of alteration of hard and fractured limestone. The high resistivity layer (more than 25 Ωm) is not well developed in karst and composed of hard muddy limestone. This high resistivity layer is distributed at depth from 60 to 110m in the study area. The borehole drilled at the wastewater treatment plant (WTP) encountered this layer at depth of 62 m (Boring P4). This layer is compact and hard. It composes impermeable or semi-permeable hydrogeologic basement in the study area. Drilling velocity ranges from 400 to 1,200sec/0.25m.

5) Groundwater level of the boring sites ranges from 4 to 8m below ground surface. The thickness of the freshwater is about 20 m, but it increases more than 40 m in the inland area according to the geophysical survey. The seawater exists under the freshwater widely in the inland area.

6) According to the dilution tests, estimated range of permeability coefficient in U1 and U2 layer is 1.1 to 22.0 cm/sec.

12.5.1.2 Behavior of Wastewater Plume

1) The CNA injection well inventory shows that the number of the injection wells in Solidaridad province is 184 in notification basis. The daily injection volume runs up to 73,051 m^3, which is 397 m^3/day per well in average.

2) Treated wastewater is being injected into the injection well in the CAPA WTP in Playa del Carmen 3,880 m^3 per day (45 l/s). In addition to this well, another injection well is utilized for injecting untreated wastewater which exceeds ability of the WTP. It is said that the depth of these well is about 100m. But the record on the well drilling does not exist. Considering the geologic condition of the WTP, it is inferred that the wastewater is being injected into U2 layer.

3) Almost all injection wells in the study area have their well screens in U2 layer (seawater aquifer) as well as the WTP considering geologic conditions. There exists no significant impermeable layer between U2 layer and overlying U1 layer（freshwater aquifer）.Thereby it is inferred that the injected wastewater migrates upward to the freshwater aquifer. In addition, it flows through the annulus to the freshwater aquifer as the well is not sealed.

4) A mass transport model which simulates the behavior of the wastewater plume indicates that the plume migrates rapidly in horizontal direction in the seawater aquifer, if the permeability of injected zone is higher than that of underlying and overlying layers. Therefore, it is important to know the permeability of the layer, first. The injection zone should be deep as possible and the screen must be placed beneath the low permeable layer.

5) It is more important to know the anisotropy of the permeability in the layer. The simulation results suggest that the wastewater plume does not flow upward and affect overlying freshwater aquifer if vertical to horizontal ratio of the permeability is less than 1/40.

6) According to the density dependent flow model, the wastewater plume injected in the seawater aquifer migrates upward and affects the freshwater in case of the 100 m depth injection well.

12.5.1.3 Water Quality and Contamination

1) Groundwater quality of the monitoring wells shows (Na+K)-Cl type. Chloride concentration of the monitoring wells installed in the freshwater aquifer shows 600～1,800 mg/L. They are affected by the seawater. Chloride concentration of the monitoring wells

installed in the seawater aquifer shows 11,400～11,800 mg/L . It is inferred that the water is mixed with shallow fresh groundwater due to fully screened well structure. .

2) Comparing the water quality of the monitoring wells with WHO guideline value of drinking water, Cl, Na and TDS exceed the guideline in all the wells. High concentration of NH_4 was detected at the monitoring wells in WTP. This well was contaminated by the injection well located just upstream of the monitoring site. The monitoring well in Colonia Ejidal, which is not covered by the sewer system, shows high concentration of NH_4 indicating man-made contamination. High concentration of SO_4 was also found at the monitoring wells in WTP.

3) Contamination of trichloroethylene and heavy minerals were not detected.

12.5.2 Recommendations

12.5.2.1 Necessity for Establishing Injection Norm

The municipal water supply in the 3 province of the study area rely on the well fields, which are located in the inland areas some 15～40km away from the coast. Surrounding areas of the well filed are, presently, forest, grass and farm land, and groundwater contamination has not occurred yet. However, groundwater may be contaminated in the near future due to discharge of domestic wastewater to *Cenote* and seepage of fertilizer and pesticide etc. There may be unknown underground caves in these area and groundwater flows through the caves and the aquifer to the down stream area.

On one hand, the wastewater is being injected into the underground in the coastal urban area. In Playa del Carmen area, hard muddy limestone formation is widely lying at depth from 60 to 110 m. Therefore, the wastewater is injected into overlying limestone aquifer (seawater aquifer), which is abundant in fracture and cavities. The semi-pervious or impervious layer does not exist in between the seawater aquifer and the freshwater aquifer, thereby injected wastewater plume relative easily migrates upward and contaminates the freshwater aquifer.

The injection well structure is simple at present because the injection well norm has not established yet. As the fracture and cavities are abundant in the limestone, the well annulus (space between the bore wall and the casing) was not sealed with cement and clay (such as bentonite). The wastewater may leak through the well annulus and contaminates the fresh water aquifer.

As mentioned above, groundwater contamination in the freshwater aquifer is in progress in the coastal urban areas due to the wastewater injection. Since groundwater is finally discharged to the coast, seawater environment may be contaminated in the future. The sewer

system will be developed in the near future according to the master plan proposed by this study. However, it may takes some time until the urban area is fully covered by the sewer system. For the time being, wastewater injection must be continued, accordingly. In order to reduce pollution load in the water environment, the injection norm should be established and injection be controlled adequately.

The following section presents recommendations on the matters to be considered for the establishment of the injection norm.

12.5.2.2 Injection Zone

Wastewater should be injected into a formation below the lowermost formation consisting of muddy, hard and dense layer, which is thought to be confining layer and impervious or semi-pervious. The injection zone, on the contrary, must be sufficiently permeable, porous, and thick to accept injected wastewater at the proposed injection rate without requiring excessive pressure. Ideally, the injection zone should be homogeneous. It should be of sufficient areal extent to minimize formation pressure buildup and to prevent injected wastewater from upward migration to fresh water aquifers. If such injection zone is found, the wastewater could be contained in the geological structure.

In the study area, high resistivity part of U3 layer (muddy limestone), which is lying at depth from 60 to 110m, is semi-pervious or impervious and meets the above conditions. However, presence of porous and permeable layer beneath U3 layer is not yet confirmed. If a permeable and porous limestone layer or bed exists beneath or within U3 layer, it should be utilized for an injection zone. In that case, the depth of the injection well becomes at least more than 200m and drilling cost will be doubled or more expensive. This point should further be discussed in relation with the cost for expansion of the sewer system.

12.5.2.3 Regional Geological Survey For Selection of Injection Zone

In order to select appropriate injection zone, regional geological survey should be conducted in the urban areas of 3 provinces in the study area. The survey should consist of the following items.

1) Data collection, Arrangement and Hydrogeological Mapping

Data and reports on the geological survey, borehole drilling, groundwater level and water quality etc should be collected and arranged. It is advisable that the drilling industries should assist data collection. Based on the data, the hydrogeological map of each urban area should be prepared.

2) Geophysical Survey

Geophysical survey should be conducted to explore resistivity structure and fresh water-saline water interface in each urban area. The TEM method of exploration should be performed to detect more than 400m depth. In Playa del Carmen, resistivity profile of 200 m has already been clarified. Therefore, a supplementary survey should be conducted to explore resistivity structure more than 400m depth.

3) Exploratory Borehole Drilling and Logging

Based on the arrangement of existing data (hydrogeological maps) and geophysical survey results, the exploratory borehole should be drilled at each urban areas to investigate drilling velocity, resistivity, spontaneous potential of the formations, and temperature and electric conductivity of groundwater etc. A target drilling depth is 400m.The facies and characteristics of the limestone are confirmed by observation of the core and geophysical logs. Depth and areal extent of most suitable injection zone is confirmed by analysis of rock characteristics compared with the resistivity layer. In-situ test, such as permeability test, is conducted and permeability coefficient and porosity of the formation are decided.

The depth and zone of the injection well in each urban area is standardized according to analysis of the geological survey results mentioned above.

12.5.2.4 Structure and Construction of Injection Well

The injection well should be designed and constructed such that it does not allow any fluid to escape the injection string or any fluid to migrate in the borehole to shallow fresh water aquifers.

Environmental Protection Agency (EPA) of USA is implementing “Underground Injection Control: UIC” Program and classifies the injection wells into 5 categories. Figure 1.1（left）shows an idealized design of injection well using example from Class I injection well of UIC. Municipal wastewater, hazardous waste and industrial non-hazardous liquid can be injected in the class I well. In case of hazardous wastewater, the well casing is tripled, that is the surface casing, the well casing and the injection tubing, and these casing are properly cemented on the outside. The packer is set on the bottom of the tubing.

In UIC program, the injection zone is set on the formation beneath the lower most freshwater aquifer (Underground Source of Drinking Water：USDW）.

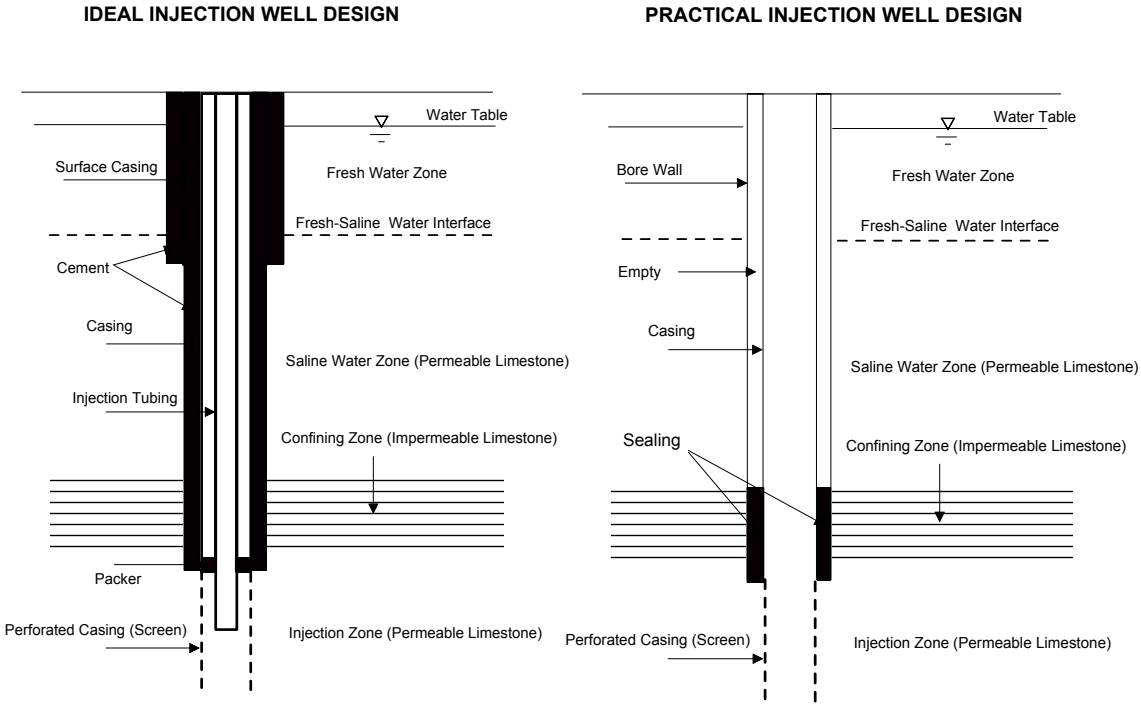


Figure 12-10: Design of Injection Well (left: Ideal design right: Practical design)

Figure 12-10（right）shows a practical design of the injection well. It was designed simple and practical considering geologic conditions and groundwater utilization in the study area. It is very important to place the perforated screen in porous and permeable zone below the confining impervious layer. If the lowermost layer above the injection zone is permeable, injected waster water migrates upward in spite of cement sealing outside the casing.

Aside from the wastewater migration in the aquifer, there are two possible well failures that causes well leakage. One is leak through hole in casing and the other is fluid movement through vertical channel in annulus. Casing rarely be damaged. However, there is a possibility of damage when it is placed in the borehole improperly. In order to avoid such damage, material and thickness of the casing should be carefully selected and the casings must be stored and used properly. In the well annulus, cement grouting must be performed sufficiently in order to avoid creation of bridge and space in annulus.

In the study area, the limestone layers (U1 and U2) which are abundant in fractures and cavities, distribute widely in the underground up to the depth of 60 to 110m. However, it is almost impossible to seal the annulus because the cement spills out in these formations. Considering this situation, the design is non-sealing in the upper formation as shown in Figure 12-10 (right). If semi-pervious or impervious layer (confining layer) exists beneath the permeable layer, another porous and permeable layer beneath the confining layer should be injection zone and the sealing is made in the zone of the confining layer.

It is rather difficult to seal the well annulus partly in the borehole. The well drilling industries should held a workshop on the materials and construction method of the injection well under the guidance of CNA, and study, level up and establish the standard method of construction.

Figure 12-11 (left) shows a conceptual design of the sealing using the packer. Figure 12-11 （right ） shows the packer material.

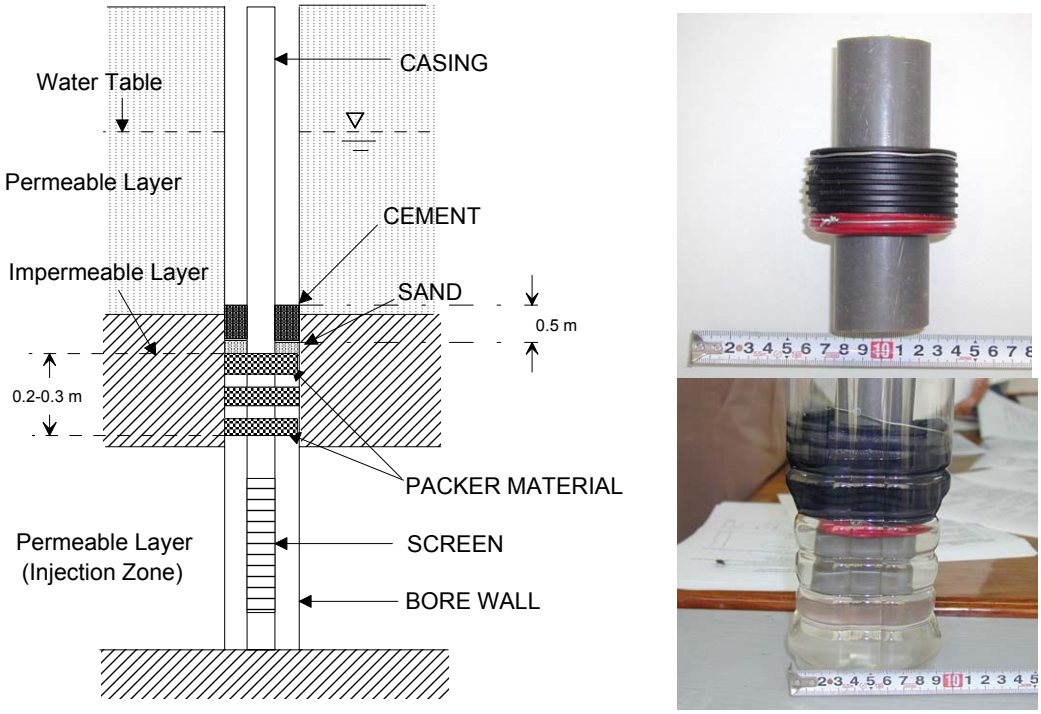


Figure 12-11: Sealing by Packer (left), Packer Material (right)

The packer material is made of acrylic acid ester and synthetic rubber. It is swollen when it absorbs water as shown in the photo. The packer material is wrapped the upper part of the casing screen in three steps and placed in the upper part of the boundary between the injection zone and the impermeable layer. One or two days after installation of the casing, the upper part of the packer is filled with sand and cement.

Figure 12-12 (left) shows a conceptual design of the sealing using the metal basket. Figure 12-12 (right) shows an example of handmade metal basket for small diameter.

The metal basket originally utilized for the land subsidence monitoring well in Niigata, Japan in order to measure water level of a specific aquifer in the multi-layered aquifers. It is thought to be applicable in the injection well in the study area.

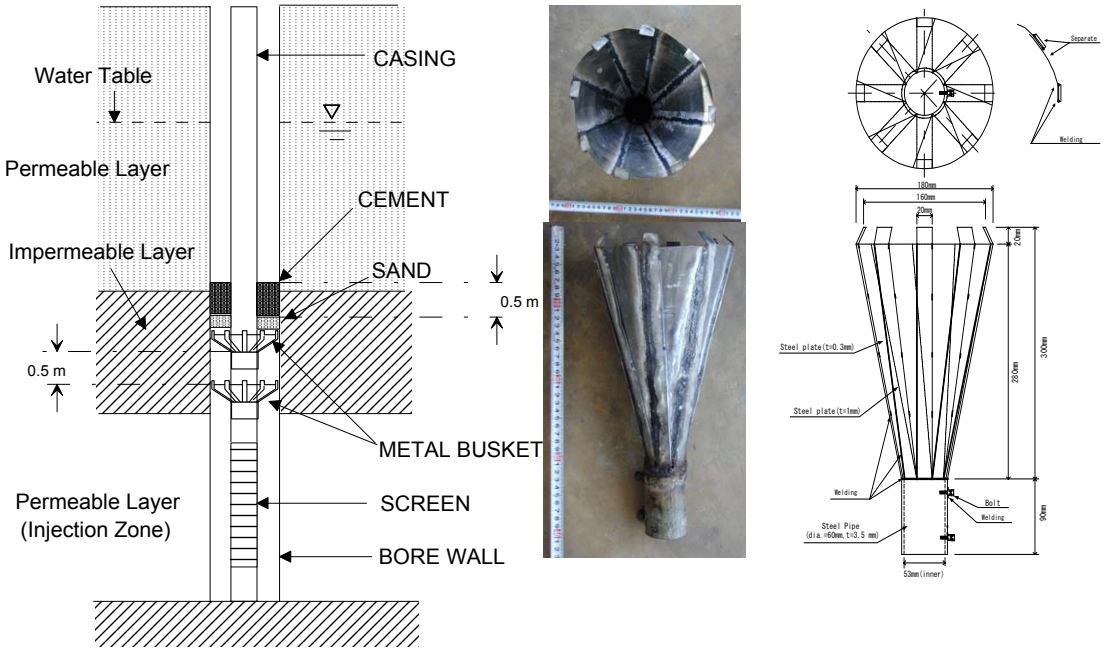


Figure 12-12: Sealing by Metal Petal Basket (left), Metal Basket (right)

Two metal baskets are installed in the upper part of the screen casing at 0.5m interval and placed in the impermeable zone. The palm leaf or net is spread out in the basket and the clay is filled inside. The metal basket opens like petals in the borehole and prevents falling of sand and cement filled in the upper part of the basket. The zone of the filling of sand and cement is decided considering the thickness of the impermeable layer.

12.5.2.5 Operation, Management and Monitoring

Notification to CNA on the injection well is necessary at present. Detail of notification includes the owner name of the well, the well location (seat) and the proposed injection rate etc. However, the structure of the well (depth, diameter, casing material, screen position, sealing etc.), columnar geologic section and quality of injected water etc are not recorded. In addition, reporting on the operation and management of the licensed well is not obligated with a loose rein. The CNA should immediately establish the system of reporting and monitoring on the operation and management of the injection well as well as the norm on the injection zone, well structure, injection rate and quality of injected water etc.

1) Operation and Management

The CNA should impose the well owner a duty on the recording of the injection pressure (in case of gravity injection, water level), the injection rate and the total injection volume. In addition to the above, the well owner must quarterly records the results of analysis of physical, chemical and biological parameters of the injected water.

2) Reporting and Inspection

The CNA receives a report from the well owner quarterly and makes on-the-spot inspections for the operation and management of the injection well in case of necessity. In order to open the way for inspection and issuance of improvement direction of the injection facilities, operation and management, the institutional and legal system should be enhanced as well as establishment of the injection norm.

3) Well Closure

Upon closing the injection wells, owner must submit a plugging and abandonment report indicating that the well was plugged in accordance with the norm and regulations enforced by the CNA in the future. In closing the well, the well should be flushed with a non-reactive fluid. Each cement plug should be tested for seal before the closure is completed.

4) Monitoring Network

The CNA established a groundwater monitoring network in the northern area of the Yucatan Peninsula bounded by the line from Cancun to Merida. This network should be expanded to the urban areas in the study area. The monitoring wells constructed in Playa Del Carmen, as a model project, should be incorporated in this network.

In addition to this network, deep observation wells should be constructed in the urban areas in order to monitor water quality and water level of the aquifer which is overlying the injection zone when the injection norm is established and the wastewater is injected into deeper aquifer than U2 layer in the future.

Chapter 13

Village Type Wastewater Treatment

13 Village Type Wastewater Treatment

13.1 Background

Although CAPA had operated sewage systems for large cities such as Chetumal and Playa del Carmen, it did not have a system for emerging small communities. Meanwhile, even in a city where a sewage system has been installed, connection of household effluent to the public sewer has not become widespread due to some reasons such as economic burden and existing septic tanks.

The mentioned above has led to a situation where the large investment cannot bring about an effect and the groundwater is continuously contaminated. In order to solve those problems, a Model Project, “the Village Type Wastewater Treatment,” was planned and carried out in Subteniente Lopez, Chetumal in the Municipality of Othon P Blanco.

Wastewater treatment facility and sewer pipes in Subteniente Lopez were constructed by CAPA. This model project was to support the CAPA’s project and so that the CAPA would gain experience which could expand such village type wastewater treatment system to the other emerging communities.

13.2 Summary

a. Achievements

The table below summarizes purposes, outcomes, inputs and results of the Model Project.

Narrative summary	Achievements
1. Overall goal Establishment of a small scale sewer system	CAPA has acquired knowledge and skills regarding social issues, e.g., encouragement of residents to connect to public sewer, and technical issues, e.g., groundwater in pouring to sewer and operation of treatment facility. Also, a manual of operation of the facility has been prepared. Thus, CAPA is ready to operate the facility and to expand the same type of small scale sewer system over the Study Area.
2. Project purpose Establishment of a fund to support residents to connect the public sewer Establishment of a design & operation manner for a small sewer treatment system	• CAPA got 99 contracts for in-house connection. • Basic conditions for building up in-house connection fund were established. • Hydraulic conditions were confirmed; however biological conditions were not confirmed due to CAPA's construction works delay.
3. Outcomes A manner to encourage introduction of a sewer system in a rural community Technology of designing, constructing and operating the sewer system is established.	• Number of used support fund for connections : 99 households were connected • CAPA learned how to get in-house connection contract. • Appropriate contract conditions for in-house connection became clear. • Comparison of original design data and actual measured data was made. Actual pumping amount was excessive. • Flow control box did not work properly. Suggestion on this problem has been made. • CAPA learned knowledge for new type facilities development (design, construction, operation, etc.)
4. Inputs 1) Personnel 2) Constriction works 3) Equipment	• Study team :Mr. Hiroshi Kato and Mr. Ichiro Kono • C/P : Mr. Juventino Castillo Pinzón, Mr. Jaime Ricardo Quiñones Baas, Mr. Jorge A. Dzul Chin, Mr. Ximenes • In-house connection works for 99 households • Supersonic flow mater • Dissolved oxygen, pH, water temperature mater

b. Other Results

Due to delay in plant construction (both piping and treatment plant) and delay in administration of contract agreement with the residents, it is now impossible to verify the actual performance of the plant with rated sewage load within the term of study. Therefore, only the hydraulic conditions were to be examined mainly.

13.3 Evaluation

13.3.1 In-house Connection

Construction of In-house Connection as well as development of sewage system play an important role of preventing contamination of the groundwater caused by domestic sewage water in the Study Area. The CAPA's responsibility was narrowed up to installation of public catch pits. And the In-house connection work was left depending on each household decision. Therefore, even though sewage system was developed, many households in the region had chosen to utilize traditional septic tank (septic hole) for their economic reasons and lack of their understanding about the impact to their livings and to the environment. As a result, investment in the field of wastewater management had not brought a real benefit to protect the human health and the environment.

Although CAPA had known that the lack of understanding about sewage and resident's tight budget were some of the reasons for delay in bringing about an effect of the investment, no practical measures were implemented. And CAPA did not have any established system or plan to promote the In-house Connection work.

This model project has;

- Set up a new foundation to encourage the In-house Connection.
- Established a new system which CAPA involves more for In-house Connection.
- Established a method of Zero-down-payment-loan.

Hereafter, the CAPA is required to collect fees and put the fund into operation with high transparency, in order to continue and expand the sustainability of the work.

In-house Connection work normally starts after the completion of sewage system development (piping and treatment facilities); however, due to time constraint, those were promoted simultaneously in this model project. As a result, some problems arouse during the operation but the CAPA has established the capacity to attack the problems. Hence, contaminated groundwater and health risk to the residents who is utilizing the groundwater in the Study Area can be expected to be reduced in the future.

13.3.2 Treatment Facility

Construction of sewage system (piping and treatment plant) within the target area in the Model Project is a jurisdiction of CAPA. The construction completion date was set at the end of December 2003; however, it was extended to the beginning of July 2004. The final In-house Connection work by the Study Team was delayed as well. And at the end of June,

the facility has no sewage water intakes. Considering the period of bacteria growth, it is impossible to conduct the performance evaluation of the treatment plant. Therefore, only the suggestions for Plant improvement were made.

The Study Team had been following the progress of construction; however, the project experienced a big delay. This is because;

- The characteristic of the region which is an extremely high groundwater level was not regarded as important factor for facility design and construction.
- Capacity of the contractor was low.

Also with regard to the pumping equipment,

- Due to the lack of experience in designing facility of water supply, proper capacity size of pumping equipment was not installed.
- And as a result, adjustable range of pump performance is narrowed.

In the future when the similar facility is to be planned and designed, use of submerged pump for sewage water is recommended since it has low suction head and also it is relatively economical.

The CAPA has accumulated considerable experiences and now is able to solve problems stated above.

Other recommendation is that the person in charge to prevent intrusion by unauthorized personnel in the plant. The treatment plant is surrounded by fences and gates, but the gates are unlocked open and anyone can enter the area. This may cause serious accidents or property loss. Some measure, such as securing the gates, should be taken so that the third personnel can not enter the prohibited area.

13.4 Conclusion and Recommendation

Due to the big delay of construction of sewage system, the initial goals were not achieved. But CAPA now appears to be capacitated toward solving problems. It is expected that CAPA expands the project following the M/P over the Study Area, utilizing this experience.

13.4.1 In-house Connection Works

The CAPA is now on the stage of utilizing an asset provided by JICA, effectively practicing the methods of contract agreement acknowledged from the Model Project. It leads to the suggestion that the in-house Connection Work be processed not only within the target area of the Model Project but in the wider study area on purpose of improvement of sewage system.

In-house Connection was designed by CAPA in this model project. But there are some disagreements of plans between CAPA and the residents, causing problems at the time of construction. The problem can be solved by promoting more dialogue with the residents and at the same time, establishing a new section which is in charge of contract agreement of In-house Connection and design/construction all together within CAPA.

13.4.2 Treatment Facility

It is impossible for Study Team to conduct the performance evaluation of the treatment plant due to the big delay of the construction of sewage system within jurisdiction of CAPA. The Study Team strongly recommends that the CAPA execute the monitoring according to the manual prepared by Study Team, and goes on to the performance evaluation and design review of the plant.

In order to avoid delay of construction work, several considerations or any measures should be made; such as, not only for the ability of construction workers, but also for types and method of survey precedes to design and construction, how to reflect the results from site survey into design and construction planning, and cost estimates based on construction planning and site inspection after contract. Those can be improved through PDCI (Plan, Do, Check, Improvement) cycle by repetitive practice.

Chapter 14

Establishment of an Integral Solid Waste Management Information System

14 Establishment of an Integral Solid Waste Management Information System

14.1 Background

It has been affirmed that the inadequate management of solid waste is contributing with 40% of the pollutant load rate (BOD) that filters to the aquifer. Such contamination is the principal motive of the high incidence of acute diarrheic diseases (DEA's by its initials in Spanish), which are affecting somehow the economy of the households and causing and increase on the poverty levels.

For that reason, the Master Plan takes into account several projects aiming to control the pollutant load rate associated to solid waste, whose main purposes are to protect the aquatic environment and to improve public health.

Therefore, it is necessary to reinforce the coordinated action of the three government levels in order to create synergy and to gain efficiency.

The new General Law for the Preservation and Management of Waste establishes the implementation of an Information System for the Integral Management of Solid Waste, whose main purpose would be the creation of a mechanism of coordination and information among the three government levels, on the subjects of sharing responsibility, prevention of the generation, valorization and the integral management of solid waste.

The Model Project aims to cooperate in the setting-up of the Information System forecasted in the General Law; likewise it intends to use this system as an instrument which may continue tracking the development of the Master Plan.

14.2 Summary

The table below summarizes purposes, outcomes, inputs and results of the Model Project.

Table 14-1: Results of the Model Project Establishment of an Integral Solid Waste Management Information System (SIGIR)

Project Summary	Results
Overall goal 1. Establishment of an Integral Waste Management Information System, which has been foreseen in the new General Law for the Prevention and Integral Management of Waste 2. M/P is implemented	The structuring and operation of SIGIR has been achieved according to the General Law. With the operation of SIGIR the recommendation of the Master Plan of setting up a system of information and coordination among the three government levels is achieved.
Project Purpose 1. The constitution of a mechanism of coordination and information among the three government levels on matters of prevention of generation, valorization and integral management of solid waste 2. Promotion and monitoring on the implementation of the M/P	The mechanism has been constituted and the participant entities keep contact through electronic communication via internet. The implementation will be promoted and monitored according to the strategy and measures proposed in the Master Plan.
Outcomes A. Information system 1.The system is established 2.The coordination among the three government levels is efficient 3. Information flows all over the system and this is sent to the National System of Environmental Information and Natural Resources B. Master Plan 4. The implementation of the M/P is promoted 5. Implementation and outcomes of the M/P are monitored by the System	A. Information system 1. SIGIR has been established in SEDUMA and in the municipalities of Othon P. Blanco and Felipe Carrillo Puerto. In each organization there is a telephone number and an email address available. 2. Personnel of the three institutions were trained in processing and registering information; the text of the new General Law was diffused as was the draft of the Regulation for the Rendering of the Public Service in the Integral Management of Urban Solid Waste; the system is used as an instrument of consultation and coordination of activities among the three organizations. SEDUMA is going to place a window in its web page concerning SIGIR with the purpose of: a) informing periodically to the public about the management of solid waste; b) demand the participation of the public in minimization programs; c) diffuse the plans and projects of the three government levels; d) collect the opinion of the public about the project of the new Regulation. 3. The information processed will be sent to the National System of Environmental Information and Natural Resources. Regrettably, this System is not yet in operation; in coordination with the Mexican C/P it was agreed to process the information and to send it to the SEMARNAT office in Quintana Roo. B. Master Plan 4. It has been agreed with the C/P that the implementation of the Master Plan will be promoted through SIGIR. This activity will start with the official appropriation of the Master Plan by the Mexican authorities. 5. SIGIR will be the instrument to be used in the monitoring of the implementation of the Master Plan 6. Other organizations of the three government levels have manifested their interest in participating in SIGIR: FONATUR, BANOBRAS, CAPA, CNA, and other municipalities in the state.

Project Summary	Results
Inputs Personnel of the S/T The work team was leaded by Ing. Victor Ojeda, who was in charge of the establishment of the strategy and design of the net. Hiram Diaz conducted the activities of installation of the system and its operation. Ing. Ximena Alegría reviewed the structure of information capture. Ing. Kunito Ishibashi reviewed the system of information of SEDUMA and suggested the procedure for the creation of a window in the web page of SEDUMA concerning SIGIR. The strategy of the model project and the development of the activities were controlled by Ing. Ikuo Mori. Personnel of the C/P The installation and operation of SIGIR in the organizations involved is in charge of the following officers (email address and telephone are from SIGIR): SEDUMA: Department of Prevention and Control Ing. Carlos Acosta, Biologist José Guerrero (projica@hotmail.com) (phone: 832 2646) Municipality of Othon P. Blanco: Department of Urban Development, Arch. Hector Morín; Department of Municipal Public Services, Dr. Rodrigo Camín. (jica3@prodigy.net.mx) phone: 285 5005 Municipality of Felipe Carrillo Puerto: Department of Municipal Public Services, Mr. Noé Baena (dspmfcp@prodigy.net.mx) phone: 267 1106 Infrastructure and materials In each organization was designed an office area in order to attend the needs of SIGIR. JICA donated a computer and gave assistance on the installation of the infrastructure for communication. The total amount donated was $25,000 pesos.	

14.3 Evaluation

a. Efficiency

The participation of the members of the S/T and the C/P has been the main support in this model project: the establishment of the strategy, design of the net, installation of the system, structure of database capture, training of personnel and operation of the system.

The contribution in infrastructure and materials was conformed by three computers with their respective operative systems and phone connections to the net and internet. The contribution of JICA was of $25,000 pesos.

The Mexican counterpart contributed with important suggestions which enriched the strategy and operation of the system; Mexican operative personnel were assigned in its moment and also room and furniture for the office were designed.

The products obtained constitute a valuable contribution in order to create more synergy among the three government levels in respect of the management of solid waste. It can be said that the contributions were used efficiently.

b. Effectiveness

All products obtained with SIGIR, in respect of the purpose of the project answer: a) what has been established in the General Law in the subject of management on solid waste information; b) to have available an instrument which may be used as a medium for coordination among the three government levels and public information; c) for promoting later on the implementation and monitoring of the Master Plan.

The establishment of an Integral Solid Waste Management Information System (SIGIR) is a precept of the General Law for the Prevention and Integral Management of Waste (General Law) (published in the Official Magazine of the Federation in October 08th, 2003 and from April 08th, 2004 has covered full effectiveness).

c. Impact

The net of information and coordination has been created and, at the moment, it constitutes a useful mechanism for the three government levels. Other governmental organizations have manifested their interest in participating in this net and integrating themselves to SIGIR.

After the delivery of the Final Report of the M/P, the monitoring of its implementation through SIGIR may take place.

Officers from CAPA have suggested that SIGIR should cover as well some aspects related to potable water, sewer and treatment, given their relationship with the management of solid waste in a common front on the protection of the aquatic environment.

The impact of the model project has been positive in terms of the achievement of the general goal to establishing SIGIR.

d. Relevance

The creation of synergy among the three government levels through the use of SIGIR as a mechanism of coordination and information will make possible that the efforts of the competent organizations reach better levels of efficiency and effectiveness.

The three government levels are obliged to assume their respective competences and responsibilities established in the General Law in the subject of: hazardous solid waste (federal government), waste of special management (state government) and municipal solid waste (municipalities).

Likewise, the General Law establishes the responsibility that concerns the productive sector and the community in general in regards of shared responsibility, prevention of the generation, valorization and integral management of solid waste.

These responsibilities as well as the incentives that are foreseen in the General Law, should be from the knowledge of generators of SW of all nature. Likewise should be all information concerning the costs in the rendering of the service, foreseen investments, legislation and other topics of public interest.

The monitoring of the implementation of the M/P will have a special relevance in all its aspects and in particular, the sustainability of the services.

e. Sustainability

The strict observance of the General Law will assure the sustainability of SIGIR. The permanent operation of the Integral Management of Waste is a precept of the General Law that must be achieved.

The three government levels are obliged to deliver, to the National System of Environmental Information and Natural Resources, created by the General Law of Protection to the Environment, all information concerning the integral management of solid waste that is in the realm of their respective competences.

Therefore, each government organ has a scope of responsibility and action and must report the activities, achievements and obstacles in the attainment of its objectives and goals.

The General Law establishes as well, that it is compulsory to inform periodically to the public all the results of the integral management of solid waste.

The system has all necessary infrastructure and the personnel designed for its operation is well trained; the organizations linked through the net have said that SIGIR is a utile mechanism for the achievement of their obligations associated with the integral management of solid waste and their responsibility with the protection of the aquatic environment and at the same time they are able to operate the system in an independent way.

14.4 Conclusions and Recommendations

a. Conclusions

- The establishment of SIGIR responds to a precept of the General Law and to an evident need of creating more synergy among the three government levels for taking care of the integral management of solid waste in the scope of their respective competences.
- The organizations linked through the net agree in the importance of SIGIR as a mechanism of information and coordination among them.

- SIGIR is an ideal instrument which informs the public and which accomplish the general participation in the subject of shared responsibility, prevention on the generation, valorization and integral management of solid waste.

b. Recommendations

- To assign in a permanent basis an operator for SIGIR in each participant organization.
- Routinely prepare and send to the National System of Environmental Information and Natural Resources, the information foreseen in the General Law. The Department of SEMARNAT in Quintana Roo will receive and register such information while the National System is activated.
- In the moment when the program of implementation of the Master Plan be prepared, its monitoring will start.
- SIGIR should incorporate other organizations of the three government levels and specially the other municipalities of Quintana Roo state in the subject of solid waste management.
- SIGIR would be able to link all organizations that will be in charge of the implementation of the Master Plan in the subject of wastewater management and specially the protection to the aquifer and the aquatic environment in general.
- SIGR may be an ideal instrument for starting the structure of the Executive Unit of the Master Plan. SEDUMA is suggested as the coordinating organ for this Executive Unit.
- JICA should consider an electronic connection with SIGIR and the possible Executive Unit, with the purpose of giving continuity and assistance to the implementation of the Master Plan during the period of execution (2004-2015).

Chapter 15

Capacity Building of Executing Agency in Othon P Blnaco

15 Capacity Building of Executing Agency in Othon P. Blanco

15.1 Background

Solid waste management (SWM) is a service provided by the Othon P. Blanco (OPB) municipal government, where municipal finances has been sound, showing surplus of around 6% in 2001 and 2002. However, following a pattern common in many cities in the world, the SWM in OPB has faced financial imbalance, since income from SWM user charges covered only a minimal fraction of SWM cost, 6.25% in 2001 and 6.31% in 2002. The income from SWM user charges accounted for 0.68% of municipal income in 2001 and 0.73% in 2002. On the other hand, the SWM cost as a proportion of municipal expenditures increased from 11.5% in 2001 to 12.4% in 2002. The following Table shows the financial characteristics mentioned above.

Table 15-1: Financial Aspects of OPB Municipality & SWM

Item	2001	2002
Income surplus (% of total municipal income)	5.62	6.21
Income from user charges of SWM (% of costs of SWM)	6.25	6.31
Costs of SWM (% of total municipal expenditures)	11.50	12.39
Cost per ton assuming a generation of 120 ton/day (Pesos)	501.59	569.10
Income per ton assuming generation of 120 ton/day (Pesos)	31.33	35.92

Source: Ayuntamiento OPB

In general, financial imbalance can result from low income, high cost, or both. Insufficient income in SWM service in OPB resulted partly from the fact that user charges were imposed only on business firms (7,919 paying firms in January 2003), while no obligation existed for households to pay user charges for SWM service. The income potential from households is high since the projected population in Chetumal in 2002 (2003) was 127,372 (130,257), resulting in 29,621 (30,292) households, based on average family size of 4.3.

The income side of the financial problem is likely to have a political solution, since a recent Federal Law (Ley General para la Prevención y Gestión Integral de los Residuos) passed on 8 October 2003 established as an obligation for all users of the SWM service to pay user charges. In accordance with this new Federal Law, the Study Team prepared a municipal regulation on SWM in the Study Area, and when this regulation is passed by one or all three of the Municipalities in the Study Area, all users of the SWM service – including households – in a Municipality will have the obligation to pay the corresponding user charges. Then, if SWM user charges are set at the appropriate levels and updated periodically, income improvement can be expected from the proper application and enforcement of the proposed municipal regulation on SWM.

The Study Team considered that improved understanding of the SWM cost by the OPB municipal government officers would have to be given a higher priority, taking into account the following facts: (1) lack of cost accounting specific to SWM; (2) cost estimation of SWM requiring special requests to the Accounting Section, without being a routine operation; (3) cost estimation based on the tracking down of appropriate accounts of the government budgeting system; (4) difficulty in monitoring cost performance of SWM activities over time due to the shortage of quantified indicators (for example, cost per ton of solid waste collection over time); and (5) the lack of cost performance indicators by SWM activity resulting in difficulty to focus and guide improvement measures.

15.2 Summary

The table below summarizes purposes, outcomes, inputs and results of the Model Project.

Narrative Summary	Achievements
Overall Goal Implementation of the Master Plan	The continued application of the suggested software for the systematic record keeping and calculation of solid waste management cost, as a tool for cost control, can open the door to the financial self-sufficiency of the service.
Purpose of the Model Project Calculation and control of the cost of solid waste management in a routine way, and formation of a mind set, attitude or awareness on provision of SWM on the basis of costs and revenues specific to the service, so as to seek the financial self-sufficiency of the service	The city government of Othón P. Blanco has installed and has used the software COSEPRE for the systematic record keeping of the cost of SWM and the calculation of the costs of solid waste collection and final disposal. The scope of the Model Project has been restricted to the data collected in the Model Projects on Collection Improvement and Landfill Improvement, with the cooperation of other municipal offices which are in charge of data on unit costs and prices, but the scope can be easily expanded to encompass all activities of the service such as street sweeping and parks.
Outcomes 1. Mechanism to collect the necessary data from other municipal offices 2. System to organize and process the collected data for input into the software 3. Criteria for the input of the collected data	1. A mechanism has been established to collect the necessary data which are handled by other municipal offices. Communication channels have been opened and cooperation has improved noticeably during the implementation of the Model Project. 2. The collected data frequently require prior processing for the input into the software, and for this purpose, appropriate tables or forms have been prepared. 3. The above mentioned data processing requires some criteria, sometimes based on accounting, other times based on reality, and these criteria have been transmitted to the municipal officers appointed for the implementation of the Model Project.
Input 1. Personnel 2. Softwares	1. Mr. Masaru Obara, a member of the S/T was responsible for the Model Project, with the close support of Mrs. Ximena Alegría and Mr. Ikuo Mori. During the absence of the S/T, Mr. Hiram Díaz was in charge of the follow up. On the C/P side, Mr. Héctor Morín, architect, was in charge of the Model Project, with the cooperation of Miss Maria Dolores Velazco Té, architect, and Miss Lilibet Eunice Arjona Pérez, biologist. 2. The software COSEPRE has been handed over with its Manual, as the basic software for the calculation and control of SWM costs. The software operates on an annual basis. Tables or forms have been prepared to facilitate collection and processing of data as summaries of groups of data prior to data input into the software. In addition, for the calculation and control of costs over more flexible analytical periods, the software “Costos de MRS” and its Manual have been prepared.

15.3 Evaluation

15.3.1 General Evaluation

The software COSEPRE for the systematic record keeping and calculation of SWM costs has been installed in several computers of the municipal government, and its application has been understood by the concerned municipal officers. The software is being used to calculate the cost of SWM, specifically the cost of solid waste collection and the cost of final disposal. The cost calculation is the basis for the control of SWM costs, and this effort is expected to continue into the future.

In addition, in order to give more flexibility to the effort to calculate and control the SWM costs, a specific software and its Manual has been prepared. This specific software is known as "Costos de MRS", and will serve to calculate and control the direct costs of SWM during periods of analysis that can be set according to the interest of the analyst or the decision maker. It is a flexible program that makes it possible the calculation of direct costs for any length of time, from one to several days, although the probable minimum analytical period would be a week or two weeks.

a. Efficiency

The cost of the Model Project is estimated at 10,000 Pesos. In terms of cost, the Model Project can be regarded as one of high efficiency, as the potential is high for controlling and reducing costs for amounts many times larger, as the result of introducing greater efficiency in the SWM service.

The results from COSEPRE can be subjected to comparative analysis with the cost of SWM in Othón P. Blanco estimated with accounting data of 2002. Another analysis can examine whether the results obtained in the Model Project on Solid Waste Collection are reflected in the cost calculated by COSEPRE. And results from COSEPRE should be subjected to monthly comparative analysis during the three months of the Model Project, in order to analyze the evolution of the cost per ton of the service over time. These analyses can indicate the scope of the efficiency achieved.

b. Effectiveness

The Model Project can be considered as an effective instrument that can contribute to the capacity formation of an executing agency, i.e., the municipal office responsible for the provision of SWM services.

Although the financial improvement of SWM may be a small aspect in the financial improvement of the municipal government, the change in mentality or attitude in the sense of

approaching the operation of a public service on the basis of specific costs and own revenues of the service would be a step forward in the municipal public administration. If this mentality or attitude could be expanded to other aspects of municipal administration, it would be a valuable contribution in the capacity formation of an executing agency in the municipal government.

c. Impact

A high impact potential has been established, depending on such factors as the real use and continued application of the software, the correct interpretation of obtained results, and the practical use of these results for making corrections in the activities of the SWM that may be incurring high costs.

It is expected that the importance of approaching a municipal service on the basis of its costs and revenues will continue to be understood and will continue to be of interest to the municipal authorities responsible for making the relevant decisions. It is important to collect the necessary data, to process the data and input into the software in order to obtain the results. But the real importance rests upon the correct interpretation of the results, and the use of these results for the decision making to improve the SWM services. If this practice becomes a routine activity, the impact will be high.

d. Relevance

The relevance of the Model Project is unquestionable as the systematic record keeping of costs and the calculation of costs as the instrument to control the SWM costs can become a routine task instead of being an extraordinary task that is tackled only in response to a special request.

Once the record keeping and calculation of costs become a routine task, it would facilitate the monitoring of costs over time, and this permanent monitoring will make it possible to make decisions in a timely fashion to introduce the countermeasures leading to the reduction of SWM costs and to the financial self-sufficiency of SWM.

e. Sustainability

The application and the routine use of the software can be sustainable depending on the continued interest of the concerned municipal authorities who are responsible for making the relevant decisions and have strong and sincere interests to make the SWM service more efficient.

The COSEPRE software is being operated by two employees of the municipal government who were appointed for the implementation of the Model Project. The experience acquired by

these two employees should be continued and expanded with the unfailing support from their supervisors as well as the municipal authorities directly responsible for SWM and the financial management of the municipal government.

15.3.2 Inherent Aspects to the Model Project

The practical application of the COSEPRE software requires a close cooperation between the different offices of the municipal government. This cooperation can be initially difficult due to a strong feeling of "ownership" over the data handled by a particular municipal office. This "ownership" feeling is understandable, but should give place to a spirit of cooperation with the purpose of attaining a common good and a common goal, the improvement of SWM. To attain and to maintain this cooperation among the different municipal offices is a constant challenge.

The data pertaining to the municipal government should be handled as a common resource by all the responsible officers in charge of the public administration of the city, and not as the property of a particular office within the municipal government. All relevant municipal officers should have access to these data, which are necessary for the design and implementation of policies, and for taking the practical measures for the benefit of the city residents.

15.4 Conclusion and Recommendation

a. Conclusion

- The awareness has been instilled into the concerned municipal officers about the need to approach the SWM service on the basis of its specific cost and revenues.
- The recommended COSEPRE software is being usefully applied in the Urban Development Office of Othon P. Blanco Municipality.
- Channels of communication and cooperation have been established among the different offices within the municipal government.
- The results obtained with the software are being subject to analysis for the practical application in the improvement of SWM services.

b. Recommendation

- The use of the COSEPRE software should be expanded to other municipal offices, specifically Accounting and Finance, and the interested municipal employees should be given the chance to learn and use the software.

- The data collection system for the COSEPRE software should be continuously improved according to the accumulation of experience by the operators of the software.
- The results obtained should be discussed among those municipal officers responsible for the SWM and those from Finance, Accounting, Human Resources, Urban Development and Education. The clear understanding of the objectives that are sought with the application of the COSEPRE software can improve the cooperation needed among the different municipal offices.
- Constant improvement should be sought in the cooperation and exchange of information among the diverse municipal offices.
- The software "Costos de MRS" was written using Microsoft Access, and should be improved and modified in order to adapt it to the peculiar needs of the municipality according to the accumulation of experience and the needs that may arise.

Chapter 16

Improvement of the Existing Disposal Site in Othon P Blnaco

16 Improvement of the Existing Disposal Site in Othon P Blanco

16.1 Background

All the solid wastes generated in Chetumal city are currently disposed in Calderitas Dump Site. The wastes disposed in this site are scattered around the area, and those wastes are exposed to the atmosphere. As a result, the water from rainfall penetrates into the wastes, causing the leachate to the ground. The leachate from wastes is pollutant water which easily contaminates groundwater.

Furthermore, the site does not have any facility to weigh the incoming solid wastes. Lack of basic data, such as weight of wastes, makes it difficult to evaluate the current condition and to achieve the successful solid waste management.

This model project is formed to solve these problems with full collaboration of the specialists among JICA study team and C/P.

16.2 Summary

The table below summarizes purposes, outcomes, inputs and results of the Model Project.

Narrative Summary	Achievements
Overall Goal • Sanitary Land-filling is to be realized by the municipality.	• The public service dept. has achieved a better understanding of land-filling operations.
Project Purpose • Improvement of the operation at the existing disposal site.	• Work loads were reduced by improvement of trafficability. • Leachate from waste was blocked off by soil compaction.
Outcomes • Waste leachate is prevented. • Fire incidents are reduced. • Easy access to garbage disposal is realized. • Waste disposal amount is known. • Computerized system is introduced.	• Wastes were compacted and covered with soil. • Fire incidents did not occur. • Perimeter roads were constructed. • Weigh bridge has been utilized. Data obtained told average waste disposal amount was 161.6 ton/day.
Inputs • Professional personnel with assistants from both S/T and C/P were assigned to the project. • The allocation of funds: $16 millions pesos. • Operation manuals were provided by S/T. • Advice & guidance were given by S/T to C/P. • C/P has carried the plan into practice. • Two bulldozers have been equipped by C/P. • Survey and investigation are conducted in order to examine the existing condition, and then plan and implement for the project in collaboration. • Facilities are designed w/ O&M plan by S/T.	

16.3 Evaluation

The project was evaluated based on the PDM, as well as findings from observations and interviews were applied.

The quantity of the inputs, such as the project fund, was small in amount but the quality of inputs, such as the professional personnel, was high. Thus, this project has achieved the "*EFFICIENCY"*. It is also necessary to state that the administrative management of the project was comprehensive and excellent.

The project purpose was to improve the operation of the existing disposal site. This purpose has been achieved by the outcomes of; leachate control, reduction of fire incidents, forest regeneration, and daily recording of waste disposal amount by computerized system. Those outcomes are crucial factors and closely related to the project purpose; therefore, the *"EFFECTIVENESS"* has been fulfilled.

The FONATUR is now considering helping the municipality arrange financing for construction of Sanitary Land-fillings in Costa Maya. This is a significant impact which the project has made. There is no other findings of *"IMPACT"* on economy, society and politics, however, this project has raised attentions of certain group of people how the garbage treatment could affect the environment in their region. The site workers and managerial stuff has gained a knowledge of land-fillings and now have an overall view of its operation and management. Thus the technical *"IMPACT"* has been brought to the people who work at the land-filling as well.

Since the environment is one of the top issues in development in Mexico, this project has succeeded the *"RELEVANCY"*.

The *"SUSTAINABILITY"* can not be recognized at this moment. The land-filling operation has been realized as a project; however, realization of the further operation is still questionable. Establishment of a new funding system is the key for the continuous operation.

16.4 Conclusion and Recommendation

a. Conclusion

As a conclusion, there are several elements brought out from the results being discussed here.

First of all, the model project has been successful within the term of the project; however, there is a little doubt that the Sanitary Land-filling to be prosperous after its handover. Apparently, the municipality is facing a lack of budget allocation toward the waste operation, because the municipality is greatly depending on funding from the central government. It is

very difficult to continue the public work, such as waste collection, without collecting fees from the residents who receive the public services. This is probably one of the reasons why an on-site bulldozer has been torn down for a while.

Second of all, although there is a few negative circumstances found out through the project, this project seems to be completed successfully. It follows that the obvious difference of the outcomes between the improved Land-filling and previous dumping is easily discovered within the site.

Vegetation on the soil over the waste has revived. It preferably hardens the ground, and for this reason, prevents the land sliding.

Also the construction of new access roads has achieved the reduction of the work loads. This fact indicates that they are pioneering to attacking the problems within their capacity.

The amount of wastes was assumed to be 100 ton/day in weight, or 200 m^3/day in volume after compaction. Those numbers were calculated based on the population in the target area. However, the actual amount of wastes was 162 ton/day or 324 m^3/day in average, which is a bit larger than the estimated. The result indicates that the dumping site will be over flown before the estimated life time of 5.1 years. It can be assumed that there are some excess of wastes but the types are not known.

Finally, at the sequence of record keeping, there are some errors made by humans; however, it is a clear indication that the act of record keeping is gradually taking root as one of their responsibility. From this point of view, a positive change of working habits can be expected within the short period of time. As a result, the amount of solid waste disposed is known, and this fact leads to the successful solid waste management.

b. Recommendation

The conclusions stated above can draw recommendations as follow.

For a purpose of utilizing as much the capacity of the landfill as possible, more frequent operation of waste compaction and soil coverage are encouraged. Some action should be taken immediately so that disposal machineries are kept up with their daily loads. Besides, a course of inspection and maintenance is an important component of machinery operation.

The best solution to stop overflow in a land-fill is to reduce the amount of excess wastes. The amount of excess wastes can be determined by the classification of collected solid wastes.

Finally, the municipality has strengthened their capability to operate the disposal site properly by means of implementing the model project. This is an indication that the municipality is technically prepared to operate sanitary land-fillings. And probably this is the best time to

take another run for reconsidering the suspended project, which is a new land-filling facility in the area adjacent to the existing disposal site.

Chapter 17

Collection Service Improvement in Othon P Blanco

17 Collection Service Improvement in Othón P. Blanco

17.1 Background

The collection service provided at the municipality of Othón P. Blanco is carried out by the Head Office of Municipal Public Services in the city of Chetumal, the municipal seat and its surrounding villages. In the rest of the territory the service is handled directly by Mayoralties with funds allocated by the municipality.

The service depending on the Head Office of Municipal Public Services is conducted directly by the Department of Public Image, which schedules the collection service on a rather elemental basis, which allows for the establishment of collection areas and assignment of vehicles and staff. Nevertheless, the current planning hinders the maximization of the resources, as well as the control on the service; and yet the latter has been planned to attain a 100% coverage, it falls short of this object, being evidence of that the accumulation of wastes on public thoroughfare in some locations of the city, or the presence of illegal dumping sites at vacant property.

In general terms, it can be stated that on the one hand the collection service under the Head Office of Municipal Public Services is efficient, since it collects most of the wastes generated at the coverage area; but on the other hand, is lacks efficiency given the inadequate exploitation of the resources, which consequently has an impact upon the costs of the service.

The cost hike due to an inappropriate planning, plus the lack of money collection for the service, will eventually render this service inadequate in the short run, and event the collapse of the same; therefore, measures have to be taken at once to prevent such scenario.

On the other hand, for the rest of the villages that render some collection service, it is based on the needs and availability of funds, and therefore the mayoralties, boroughs or sub-boroughs lack the adequate infrastructure that allows for the planning, design and monitoring of an efficient collection service.

In addition, the allocation of resources from the municipality does not always fit the real needs of each location, and thus there are some locations where funding is insufficient, while in others the resources are underexploited.

Taking the above as a whole, it can be said that municipal solid waste collection in Othón P. Blanco is inefficient, given the lack of planning and design of the service, additionally to the inappropriate organization of the same that prevents the integral management of the wastes

and, in consequence, the attainment of economies of scale. This situation greatly adds up to the costs of the service and curtails the possibilities of raising the service coverage due to the lack of budget.

In order to revert the status quo, a project oriented at the improvement of the current collection service is deemed convenient, so as to achieve a level of efficiency that allows, in the short term, for a considerable cost reduction and an enhanced quality of the same; as well as the reinforcement of the system's organization so that waste management can be integrally outlined and a better allocation of resources can be achieved, which in turn will contribute to expand coverage towards outer locations.

17.2 Summary

a. Achievements

The table below summarizes purposes, outcomes, inputs and results of the Model Project.

Narrative Summary	Achievements
General Goal M/P is implemented	With the implementation of the model project, the use of resources has been optimized as well as the costs of the service have been reduced. The savings achieved may be destined to augmenting the coverage in collection in other localities or in improving the final disposal of waste, achieving in this way two particular objectives of the M/P: "To provide an adequate living environment" through the removal of waste from households and communities and "to mitigate the impact to the environment caused by wastes" through a proper disposal of collected waste. The incorporation of other localities to the program of optimization of the service will allow extending the coverage of the collection service, achieving the implementation of the M/P.
Purpose of the Project Improvement in the efficiency of collection service in Chetumal	With the implementation of the model project, the planning and optimization of the routes was achieved, improving the efficiency on the collection by reducing the shift, the distance traveled and by increasing the efficiency of the resources, achieving in this way the purpose of the project. The operation of the monitoring system and control of routes, has delivered enough and necessary information, through which the D.M.P.S. has designed a program in order to optimize the routes with less efficiency. The program of control of routes permitted to detect anomalies in the use of resources, putting the D.M.P.S. a set of measures to control and remove such situations, which will positively impact in the efficiency of the service. The optimized routes have a diagramming and control points that facilitate the supervision and avoid the way out of the journey, like happened before. The information generated makes easier to the D.M.P.S. to develop the budget for the service and at the same time to study a tariff for charging the service.
Collection service improvement in small localities	A technical unit is under operation. This unit is formed by personnel of the D.M.P.S. and representatives of the city halls in Calderitas and Bacalar. This unit is actually carrying out the analysis of the service and elaborating a program for the optimization of the service in such localities.
Outcomes 1. The collection costs are reduced	Through the optimization of the routes was achieved: Reducing the total time of operation of a truck in 11%. Reducing the hours paid to operative personnel in 11%. Increasing the total tons collected per hour in 3% as medium value and 10% as maximum value. Increasing the efficiency of the tons collected per assistant in 8% and in average 3%. The previous results reflect a reduction in the direct costs of the service, among them combustible, lubricants, maintenance of the vehicle and cost of personnel.
2. Collection is programmed	The diagramming planes for each route that was optimized were made, indicating in them the starting and completion points of each journey, besides of the location of control points for supervision. The Direction of Municipal Public Services incorporated within its administrative and operational process the use of the "route sheet" for gathering information in all the collection routes. Two calculus books were designed and put into operation in excel format. These books allow recording the information gathered in the route sheet, the consolidation of information per route and vehicle, the estimation of resources used (manpower, vehicle) and estimation of quality indicators. These instruments are used for the whole service. The D.M.P.S. allocated two informatics technicians for the management of information of the collection service, who at the same time are in charge of the information relative to the entry of vehicles to the dumping site. The coordination of both activities allows comparing both services, to detect if there are discrepancies between them, the causes and to inform to their superiors for the application of corrective measures.

Narrative Summary	Achievements
	The application of quality indicators for all the routes came into operation; goal values were established for each one of them and a table of priorities was designed for the optimization of the routes. A program of supervision in the field was implemented in order to verify the execution of the journeys and the quality of the service. Such supervision is programmed in function of the efficiency measured for each route. The D.M.P.S. decided to elaborate a monthly report which details the operation of the collection service, including an analysis of its efficiency. The purpose is to evaluate the service, to have the necessary antecedents in order to effect the changes and to elaborate budgets. Technical and informatics personnel are in condition of implementing the optimization of the other routes and to make that 100% of them respond to an optimum design.
A manual for the improvement in the collection service is prepared	A procedures manual was elaborated for the optimization of the collection routes. An instructive for the recording of data and the use of the calculus book was elaborated. Personnel were trained on the use of both documents.
The coordination between the municipality and small localities is fortified	Coordination meetings were carried out among the organizations involved and the Technical Unit was created. The localities are operating the route sheet, performing the monitoring of the routes and sending the information to the D.M.P.S. The D.M.P.S. is giving technical support to the localities for the optimization of the service. The elaboration of a monthly report came into operation with the background of the services in Chetumal and in other localities and the technical and economical evaluation of each service.

Contributions

Personnel S/T

The study team was leaded by Ing. Ximena Alegria, who was in charge of coordinating the strategy, planning, designing and conducting the activities. Lic. Hiram Diaz was in charge of the coordination of information between the D.M.P.S. and the S/T. Lic Citlalli Suarez conducted the public opinion survey. Ing. Mario Valle compiled and analyzed information from several sources.

Personnel C/P

Dr. Rodrigo Camin, Director of D.M.P.S. was responsible of the decisions adopted during the development of the project, of the incorporation of new procedures to the service and of coordination with other localities. Ing. Jose Tut Wan was in charge of the revision of coordination of the activities between the D.M.P.S. and the S/T. The technicians Jose Mendez and Edilberto Quintero participated in the process of design of the routes and in the implementation and control of the same. The informatics technicians Angelina Tut and Roberto Tun were in charge of managing and processing the information as well as the elaboration of the reports.

Equipment

The S/T donated to the municipality of Othon P. Blanco a computer and a printer, which were installed in the offices of the D.M.P.S. in order to control the collection service.

b. Other results

In the following table are shown the results of the variables monitored during the development of the project.

Table 17-1: Results of the monitoring of the routes

Route Nº	Data	Initial	Model Project		
			March	April	May
	Worked days	25	27	25	26
	Totality of journeys	50	54	52	53
	Totality of tons	179	193	179	186
2	Totality of assistants	54	54	50	52
	Hours/month	245	240	223	226
	Hr. Collection/month	184	186	185	184
	Total combustible	1.250	1.350	1.250	1.250
	Worked days	27	27	27	25
	Totality of journeys	54	51	51	48
	Totality of tons	176	176	176	163
4	Totality of assistants	54	54	54	49
	Hours/month	245	239	236	216
	Hr. Collection/month	190	193	188	170
	Total combustible	1.350	1.350	1.350	1.250
	Worked days	13	15	11	13
	Totality of journeys	26	30	21	27
	Totality of tons	118	136	100	118
9	Totality of assistants	26	30	22	26
	Hours/month	132	123	92	112
	Hr. Collection/month	83	87	69	89
	Total combustible	650	750	550	650
	Worked days	12	13	10	12
	Totality of journeys	24	26	19	23
	Totality of tons	97	105	81	97
23	Totality of assistants	24	26	20	22
	Hours/month	128	111	80	103
	Hr. Collection/month	84	83	59	81
	Total combustible	600	650	500	600

Data on tonnage is included only for the month of May, period where the weighbridge in Calderitas worked in a permanent basis.

17.3 Evaluation

Considering that in the first months there is no information on the amount of tons collected, and due that the routes that were optimized serve the same area, in order to evaluate the indicators related to the weight of waste, an average weight per journey has been determined, with base on the information obtained from May. The estimation of previous months was based on the information from May.

17.3.1 Efficiency

a. Worked hours per month

With the optimization of the routes it has been possible to reduce the hours worked per month, considering the routes in 11%. In route 2 the reduction achieved is 8%, for route 4 is 12%, for route 9 is 15% and for route 23 is 19%. This reduction in the times of work is due to the increase in the efficiency of the collection (ton/hour), increase in the efficiency of workers (ton/assistant/day), execution of the diagramming of the routes and the lower distance traveled, which, according to the new journeys was reduced in a 15%.

The lower amount of hours worked per month impacts in the hours of operation of the vehicles, reducing them in the rate indicated previously. With this it is possible to reduce the maintenance costs, combustible and lubricants.

The lower amount of worked hours also impacts in the costs of personnel, because the hours per shift have been reduced. In case of route 2 there was a reduction of 10%, for route 4 in 4%, for route 9 in 17% and in route 23 in 21%, giving as an average a reduction of 11%.

Currently, the D.M.P.S. has established a bonus system for the workers besides their salaries, in order to cover extra hours. As the results have shown, the other routes can be optimized and performed within the shift and therefore this bonus can be eliminated, causing higher economies to the service.

b. Collection hours vs. worked hours

Through the optimization of the routes it was possible to increase the amount of hours dedicated to collection and to reduce the totality of hours worked. This was due to the diagramming of the routes and to their supervision, which avoided that the vehicle went off the route in order to collect waste from other sectors that were not their responsibility.

With the model project, the collection hours represent 79% of the total time; before 72% was dedicated to collection. This, together with the reduction of the total time worked, indicates that the efficiency in the collection per hour has increased.

c. Collected tons vs. collection time and total time

The total tons collected per collection hour in average increased in 3%, being 1% for routes 4 and 9, 3% for route 2 and 10% for route 23.

By the same token increased the efficiency of collected tons per worked hours, reaching 13% considering the four routes; the higher increase in efficiency was in route 23, i.e. 24% and the lower in route 2, which only achieved 5%.

The efficiencies achieved are under the optimum settled as goal, i.e. 2,0 ton/hr per collection. The route with better efficiency is route 9, with 72% of the goal value, which is owe to the high collection of pruning waste (branches, small logs, leaves, etc.) which demands quite a lot of time, besides that the vehicle completes its load by volume and not by weight.

d. Tons vs. assistant day

The daily efficiency of the collection assistant increased in 3%. The increment was higher in route 2, reaching 8%, in routes 4 and 9 the increment was minimal and in route 23 it reached 3%. Efficiency is highly affected by the way in which users dispose their wastes or the place where they store it, especially for routes 2 and 4 because in many occasions collectors have to enter private properties in order to withdraw the wastes, considerably delaying their labor. With respect of the fixed goal value, route 9 accomplished to have optimum efficiency, route 23 attained 93% of the optimum and the routes 2 and 4 are under the optimum, attaining 80% and 73% respectively of the value.

e. Consumption of combustible

The reduction of the work hours per month and the reduction of the distance traveled impact in the consumption of combustible; therefore it is expected a reduction of this expenditure. However, as the D.M.P.S. keeps into operation the system of allocation of a fixed amount to the vehicle per day; it was not possible to determine the real expenditure and therefore the reduction achieved.

If the reduction achieved when the truck is operating is analyzed, as well as the distance traveled per month and the increase of the collection hours, then the consumption of combustible should experience a reduction of approximately 10% in relation to the initial consumption that not necessarily coincides with the value allocated.

17.3.2 Effectiveness

The purpose of the project was achieved because the design of the routes allowed improving the efficiency on collection, personnel, on reducing the distances traveled as well as the work shift.

With the optimization of the routes, it was possible to have control over resources, their quantification and their minimization.

The optimization of the service and the control over resources allowed reducing considerably the direct costs of the collection service in the routes that were optimized. The application of this model to other routes will generate important savings to the D.M.P.S. who will be able to use them in the improvement of the final disposal of waste, accomplishing like this the goals of the M/P.

17.3.3 Impact

A main positive impact of the model project is that the D.M.P.S. has been able to prove that it is possible to have a collection service that responds to a planning and technical design through which it is possible to supervise the service, to reduce the costs and to offer a quality service.

The above-mentioned has had a positive impact on the procedures of the D.M.P.S. because decisions that allowed the incorporation of new systems of control and supervision have been taken in the field as well as through the processing of information. Additionally, some measures for the control of resources have been taken, i.e. in the management of combustible and in the selection of ideal personnel.

The implementation of the model project has had a positive impact on the direct costs of the service, reducing the costs of personnel, maintenance, combustible and lubricants.

The project has had a strong impact on the behavior of workers; the supervision has prevented them from using vehicles for the collection of private waste and for improving their efficiency.

As far as the D.M.P.S. has obtained higher information of the service, it has been able to detect problems, mainly related to personnel who make inadequate use of resources or who charges for the service. This has permitted to have a positive impact because a set of measures which allow correction and/or avoiding such bad habits have been applied while at the same time it permits to have ideal personnel for carrying out the collection tasks.

The model project has motivated all technical personnel to get involved in the different activities of the service and to actively participate in the formulation of solutions and measures that will improve the efficiency of the works.

The centralization of information of the final disposal and collection services has had a positive impact because it has integrated all the activities and has achieved that the service be managed in a global way, by incorporating other communities.

The project has had a multiplying positive impact in the D.M.P.S., firstly because it has motivated all technical personnel to get involved with the design and to set goals, which makes them to promote solutions and to carry out constant supervision in the field and in the information obtained through the processing of data. On the one hand this has motivated informatics personnel to constantly update the information and on the other hand it has obliged and motivated operative personnel to correctly execute their functions, improving the quality of the service. As result of the above-mentioned, the D.M.P.S. has generated some changes in its management that entail improving the efficiency on the service.

The processing of information has allowed having wide knowledge of the service while at the same time counting with all necessary tools which will forecast the costs and requirements of the service, aspect that was previously unknown for the municipality. Nowadays the municipality is in condition of estimating and programming annual costs and of formulating a tariff for charging the cleaning service, which will positively impact the budget of the city council.

The incorporation of other localities to the system of management of information and optimization of routes will allow improving the collection service in the municipality of Othon P. Blanco and at the same time, will allow carrying out a better distribution of resources, positively impacting all the community.

17.3.4 Relevance

The optimization of the collection routes and the minimization of costs will allow to the municipality redistributing resources, increasing those related to final disposal and allowing the implementation of the measures proposed in the M/P regarding this subject.

17.3.5 Sustainability

Through the different measures adopted by the D.M.P.S. like the new control of resources, selection of personnel, monthly evaluation of the routes, execution of the goals proposed, the program of optimization of the routes, coordination of the service with other localities, etc, the sustainability of the project is assured.

The D.M.P.S. has taken as principal objective the optimization of the collection service in order to enforce in the short term a tariff for charging users and improving this way the final disposal, aspect which is very relevant to the sustainability of the project.

The D.M.P.S. has personnel and adequate infrastructure which will allow planning, designing and operating in an efficient way the collection service.

17.4 Conclusions and recommendations

17.4.1 Conclusions

The strategy and measures proposed in the M/P are being executed.

The optimization and control achieved on the collection service has shown to the D.M.P.S. that it is possible to considerably improve the service through a rational plan of collection, which will permit not only increasing the efficiency and quality of the service but also achieving an adequate level of competitiveness and attaining important reductions of the costs.

During the development of the experience a set of problems have been evidenced; these problems affect the quality and efficiency of the service and are not related to its design but to parallel activities that drivers and collectors perform. These problems should be eliminated in the optimization of the routes in order to achieve effective results.

Besides increasing the efficiency of the service, its quality has also improved, fulfilling with the attention days, established timetables and carrying out an optimum collection. After the service is performed it is not possible to observe scattered waste on the streets. These achievements have been possible due to the constant participation of all personnel that took part in the model project, those who put in practice the knowledge obtained through the training program. The adequate diagramming and daily control of the parameters monitored by part of technical personnel, allowed making the necessary adjustments in the routes. The constant supervision of the routes assured the execution of the journeys and hence the coverage of the service. Finally, the correct execution of the route and the lifting and load of waste strongly influenced the increase on the efficiency and effectiveness of the service.

The D.M.P.S. has agreed in the importance of optimizing the service and in the need of formulating in the short term a type of charge for the cleaning service, which will allow its sustainability.

The city halls are interested in improving and controlling the collection service and are able to cooperate with the D.M.P.S. in order to achieve the objective.

17.4.2 Recommendations

With the purpose of increasing efficiency on personnel and that the savings achieved due to the optimization of the routes are reflected in lower cost of personnel, it is recommended to modify the system of payment of bonus to the personnel, paying instead exclusively for the hours worked. This may be carried out because the new system of control of routes allows knowing the hours that were effectively worked.

It is recommended to eliminate the allocation of a fixed amount of combustible per vehicle, which avoids any type of control over the resource. Nowadays there are variations over 20% of consumption for the same vehicle, which strongly impacts on the costs of the service. If the allocation is not possible according to real requirements, then it is recommended to establish it according to the characteristics of the vehicle and the route served (worked hours, distance traveled).

It is recommended to perform more supervision in the area of routes, with the purpose of assuring the execution of the journeys.

It is recommended to carry out in a separate basis the collection of household waste from vegetable waste (especially pruning waste); this is with the purpose of improving the efficiency on the collection, avoiding damages to the compactor equipment due to over size elements and using to the maximum the load capacity of the vehicle. This measure is directed to those wastes that are placed in front of the households in high volumes, in this case, the way of operation could be through the identification of the place by the driver, who could later inform to the Direction and therefore this would program a bunker truck for its collection during the afternoon shift or during the time when there are less activities. The waste collected may be taken to the dumping site, where there is a special place for the elaboration of composts.

It is recommended to acquire new trucks that can replace small trucks and dumping trucks, due to their low efficiency and because they are not suitable for the service that are currently performing. While the replacement of vehicles is carried out, it is recommended to evaluate technically and economically if it is convenient to keep using small vehicles for the collection of household waste, due to the high consumption of combustible and the low efficiency presented. Based on the results, it is proposed to evaluate the execution of the routes served by these vehicles during the afternoon shift with the compacting vehicles; instead it is proposed to use small trucks only for withdrawing pruning waste or commercial waste of high volume.

Chapter 18

Collection Service Improvement in Felipe C Puerto

18 Collection Service Improvement in Felipe Carrillo Puerto

18.1 Background

The municipality of Felipe Carrillo Puerto has low collection service coverage of municipal wastes (household, commercial, institutional, and so on). In effect, the service is carried out only in the city of Felipe Carrillo Puerto, the municipality's seat; in the remaining locations grouped as mayoralties, boroughs and sub-boroughs, only some specific programs are executed, such as the "junk waste elimination" program, which is conducted once or twice a year. In these locations, the disposal of wastes generally is takes place though the burning of the same. On the other hand, the collection service in the city of Felipe Carrillo Puerto, under charge of the Head Office of Municipal Public Services, covers only part of the area, thus serving 9, 000 inhabitants from a total of 19,000; that accounts for a 47% coverage in the city and 18% for the entire municipality.

The reasons behind this low coverage are related to the scarce budget available by the municipality for these activities, ranging from 10 to 12% of the total budget, the poor conditions of the collection vehicles and a lack of planning of the service.

Inexistence of service planning is evident since the Head Office of Municipal Public Services lacks a rational design for the service, which leads to improvising the tours, and therefore some sectors are attended twice or thrice, whereas other remain unattended. Additionally, lack of auditing of the service and information surveying prevents the Head Office and the municipality from having a clear vision of the service needs.

The above situation can be reverted if a program aimed at the improvement of the collection service is implemented, thus achieving such an efficiency that the coverage of the same can be raised in the shot term. The proposed model project aims at such improvement through the following phases:

- Designing of collection service with a technical criterion,
- Implementation of routes as per the proposed layout
- Preparation of a Plan to expand coverage
- Preparation of a Handbook that will constitute the basic tool to share the experience towards other locations

18.2 Summary

18.2.1 Achievements

The table below summarizes purposes, outcomes, inputs and results of the Model Project.

Narrative Summary	Achievements
General Goal M/P is implemented	The execution of the model project has allowed withdrawing waste from a higher number of houses and colonies, fulfilling like this one of the particular objectives of the M/P that is "to provide a sanitary living environment". In fact the collection rate in the urban area increased from 27% to 49%.
Purpose of the Project Improvement in the collection coverage in Felipe Carrillo Puerto	The city of Felipe Carrillo Puerto has a new collection service, which is provided in a continuum form and within established timetables. Using the same resources used before starting the model project, it has been possible to increase the collection coverage and to generally improve the service. With the implementation of the model project, it was possible to increase the coverage of the service in the municipality (urban area) from 27% to 49%. The M/P considers as goal for 2007 a coverage equal to 70,1% for urban group 6, conformed by Felipe Carrillo Puerto and Señor. The model project has over passed such goal, achieving a collection rate of 74%. The design of the collection service has permitted to optimize the use of resources. The improvement of the coverage becomes evident by observing that the activity of burning waste has been reduced, just like the volume of waste inadequately disposed in empty land and streets. The amount of users has increased in 78%, with respect of the initial value. These new users got used to the fact that their wastes are withdrawn from their households and inclusively, in response to that, they have improved the storage system. This is especially true for the commercial area and downtown. This has obliged the D.M.P.S. to maintain the new collection service, assuring its sustainability.
Outcomes 1. The coverage in collection is improved	✓ The new collection service was put into operation in Felipe Carrillo Puerto, whose design was based in basic criteria, which allowed the optimum use of the resources available. ✓ The number of users being attended by the new collection service is higher than 16.000 inhabitants, which represents an increment of 78% in the coverage in the city of F.C.P. ✓ Planes for the service, for each one of the routes, were made, with the corresponding diagramming, which are used by drivers in carrying out the journey and by the supervisors, in order to supervise the routes. ✓ The direction of Municipal Public Services incorporated within its administrative and operational processes the use of the Route Sheet that allows gathering field information of the services. ✓ A computer schedule was put into operation for the registering and management of data obtained through the route sheet and a schedule for the consolidation of information and the estimation of indicators. ✓ A program of field supervision was implemented in order to verify the execution of the journeys and the quality of the service. ✓ The use of indicators was enforced, setting for each one, specific goal values and evaluating each month the routes. The necessary correction was carried out. ✓ The municipality decided to incorporate to the Direction of Municipal Public Services a technician that is in charge of the computer management and processing of field information, the elaboration of monthly reports and the evaluation of routes through the use of indicators. ✓ Each month, a report is being elaborated, concerning the development of the service. In it there is contained information per route, vehicles and personnel. The consolidated information permits to control resources, mainly combustible and man hours, previous to the implementation of the model project such controls did not exist. ✓ The number of hours worked per month was reduced as well as the number of journeys. ✓ Personnel of the D.M.P.S. are trained for carrying out the design of the collection service, making possible to extend the experience to other areas of the city or communities.

Narrative Summary	Achievements
A manual for the planning and design of the collection service is prepared	✓ A procedures manual was elaborated for the design of the collection service and the optimization of the collection routes ✓ An instructive for the recording of data and the use of the calculus schedule was elaborated. ✓ Technical personnel were trained on the use of both documents.

Contributions

Personnel S/T

The study team was leaded by Ing. Ximena Alegria, who was in charge of coordinating the strategy, planning, designing and conducting the activities. Lic. Hiram Diaz was in charge of the coordination of information between the D.M.P.S. and the S/T. Lic Citlalli Suarez conducted the public opinion survey. Ing. Mario Valle compiled and analyzed information form several sources.

Personnel C/P

Ing. Eduardo Escalante from the Direction of Public Works was in charge of coordinating the activities between the Municipality and the S/T. The director of Public Services, Mr. Noe Baena was in charge of approving the new design of the collection service and the incorporation of new administrative procedures and control of the service. The technician Manuel Gongora participated in all the process for designing the routes and was in charge of all field activities. The technician Cesar Guzman was in charge of managing and processing the information. Bio. Jose Guerrero, officer of SEDUMA, carried out coordination tasks between the municipality and this organism.

Equipment

The S/T donated to the municipality of Felipe Carrillo Puerto a computer and a printer, which were installed in the offices of the D.M.P.S. in order to control the collection service. A manual was elaborated and delivered to the C/P for its revision and comments. Later on, the final version was edited.

18.2.2 Other results

In the following table are shown the results of the variables monitored and the indicators during the development of the project

✓ Population served in the project

In the following table is shown the background regarding the coverage of the collection service before and after the implementation of the model project.

Total Urban Population	33,025	Inhab.
Population Urban Group 6	21,784	Inhab.
Population Served Initially	9,000	Inhab.
Population Served With the Model Project	16,044	Inhab.
Initial Coverage Urban Area	27%	Inhab.
Initial Coverage Group 6	41%	Inhab.
Project Coverage Urban Area	49%	Inhab.
Project Coverage Urban Group 6	74%	Inhab.

✓ Results of monitoring the service.

The table shows the monthly results for the variables of control of the service.

Table 18-1: Results of monitoring the routes

Month	Worked hours	Collection hours	No. of shifts	Consumption of combustible
January	732	488	301	3,474
February	680	486	218	2,867
March	691	511	218	2,698
April	682	516	224	2,598
May	669	497	210	2,605
Average project	680.5	502.6	217.5	2,692.0

18.3 Evaluation

Due that before implementing the model project the service responded to a daily programming, where vehicles were assigned sectors or avenues, the evaluation of the project was carried out based on the monthly information of the service.

18.3.1 Efficiency

The efficiency achieved by the model project was evaluated in function of the results obtained from the different variables that were controlled during the development of the project.

a. Worked hours per month

With the operation of the new collection service it has been possible to reduce the total amount of worked hours in the whole service in 7% in relation to the initial situation. Besides, this lower amount of hours is able to serve 7,000 more users, which means that the current efficiency is 23.6 users/worked hour; before the implementation of the project the efficiency was 12 users/worked hour. Therefore, costs associated to direct manpower through the implementation of the model project have been reduced, which impacts on the tariff and permits to reduce the costs per user served.

Additionally, the hours dedicated to collection increased in 3% by implementing the model project, which together with the reduction of total hours, indicates that the vehicle is now dedicating less time to transportation and final disposal. Operating under the optimized design, from the totality of time worked, 74% is destined to collection; previously it was 67%.

b. Number of users per vehicle

This variable permits us to establish the efficiency of the vehicle. The values attained before and after the model project were 2,250 and 4,000 inhabitants/collection vehicle respectively, i.e. the number of users served by the current group of vehicles increased in 77%. By optimizing the use of this resource, it was possible to achieve the coverage proposed as well as to reduce the transportation costs.

c. Number of journeys per month

The totality of journeys per month has reduced in 28% with the application of the model project; therefore the capacity of transportation per vehicle has increased. In fact, if the per capita production adopted in the service is considered, the totality of tons per journey has increased from 0.7 ton/journey to 1,8, which means an increment in the efficiency of the

transport in 108%. This situation is the result of the application of a collection service where routes are designed under technical criteria and are not the decision of the driver. The design avoids the duality of journeys, minimizes the transportation time and assures the collection in the whole sector. The higher efficiency of transportation reduces the operative costs of the service (personnel, lubricants, combustible, maintenance, etc.).

d. Consumption of combustible

With the implementation of the model project it has been possible to reduce the monthly consumption of combustible from 3,500 L/month to 2,700 L/month. This represents a consumption of 15.6 L/ton and 7.2 L/ton of combustible respectively; achieving therefore a reduction of 54% in the costs of combustible per ton collected. The reduction on the consumption of combustible is not only the result of the implementation of an optimized design but also of an adequate and constant supervision program.

e. Costs of the service

It is evident that the efficiency achieved through the implementation of the model project has impacted on the costs of the service. While this may not be observed directly in the global costs for the municipality (monthly costs have remained almost constant), it is clear when unitary costs are evaluated. The cost of the service has an approximate value of 1.2 million pesos yearly. If the estimated production of waste is used in the design of the routes, the annual tons collected before and after the implementation of the project are 2,673 ton/year and 4,766 ton/year respectively. Therefore, with the application of the model project it was possible to take the unitary cost from 448.9 $/ton to 251.8 $/ton, which represents a reduction of 44%.

Besides increasing the efficiency of the service, its quality also improved, executing on time the established attention days and timetables, while at the same time carrying out an optimum collection service, observable in the lack of scattered wastes on the streets.

These achievements have been possible due to the constant participation of all personnel that took part in the model project; those who put in practice the knowledge obtained through the training program and at the same time learnt how to capture and manage data. These allowed the evaluation of the service, supported in the efficient use of the computer which was donated.

18.3.2 Effectiveness

The purpose of the project was achieved because it has been possible to incorporate to the collection service a total of 7,000 users, increasing the coverage of the urban area from 27%

to 49% and in the city of Felipe Carrillo Puerto from 41 to 74%, without increasing the use of resources.

The M/P has set as goal for 2007 a 70.1% collection rate for urban group 6 (the cities of Felipe Carrillo Puerto and Señor). With the implementation of the project, the collection rate achieved for the same segment of the population was approximately 73%, which shows the level of effectiveness achieved.

Additionally, under the operation of a new collection service, resources have been optimized, increasing the global efficiency of the service.

The project has been effective because it has increased the coverage and quality of the service; wastes are collected daily in the shift and timetables established (aspect that has positively impacted on the quality of life of people by reducing the burning practices and the bad disposition of waste in empty places and streets).

18.3.3 Impact

The main impact of the application of the model project has been the increment on the coverage of the collection service, achieving the values settled as goal values for year 2007 of the M/P.

It has also had a positive impact on the costs of the service, because the use of resources has been optimized.

Within the community the project has generated a set of positive impacts; maybe the most important one is related to the improvement on the quality of life, because through the collection of wastes in a regular basis, these are not burnt nor thrown in households' backyards and/or streets.

Another positive impact within the community is the formation of management of wastes' culture. The method to manage wastes has changed, now they are stored and placed in front of people's households during the time when the truck collects and inclusively, some people have incorporated the use of small containers, avoiding like this that fact that wastes remain for long periods on the streets and their dispersion by animals. This change in habits is related to changes in the management of final disposal, as was previously mentioned.

Such impacts have been positive as well for the Direction of Municipal Public Services (D.M.P.S.). The design of the collection service and the procedure for its control have had a multiplying effect, firstly because they have motivated technical personnel to get involved in both the design and establishment of goals. This produces a constant supervision on the field and on verifying the adequate use of resources. Adequate supervision of the service has

obliged and motivated personnel of operation to correctly execute their labors, improving the quality of the service. All those elements have resulted in the creation of a culture that gives sustainability to the project within the Direction.

There are also visible positive impacts on personnel, considering that some bad habits have been eliminated and work hours are distributed evenly, which is traduced in a shorter shift for all workers.

The control and development of the service has permitted to have wide knowledge about its characteristics and at the same time to count with the necessary tools to project the costs and requirements of the service, aspect that was previously unknown to the Municipality. Nowadays the municipality is in condition of programming annual costs and of formulating a tariff for charging the cleaning service, which will positively impact in the city council budget.

18.3.4 Relevance

The increment in the collection coverage and the optimization of resources, constitute a mechanism through which the goals of the M/P will be achieved. Its relevance relies in these aspects.

18.3.5 Sustainability

The project is going to be sustainable as long as the D.M.P.S. has availability on its vehicles, which is the only weak aspect of the system. The service is designed in an optimum way. Technical personnel are trained for modifying the design and operative personnel develop their functions according to what has been programmed. In relation to this aspect, the Municipality has considered to buy two collection vehicles for this year, in such case, the sustainability of the project is assured.

It is important to mention that all personnel working in the D.M.P.S. as well as other officers that participated in the model project are in fact used to the practices that demands the new collection service. Such practices originated in the first place important changes on their work behavior and what was expected from them. However, as long as some results were visible, their posture changed, modifying their habits, a really important aspect in order to assure the sustainability of the project.

18.4 Conclusions and recommendations

18.4.1 Conclusions

The strategy and measures proposed in the M/P are being executed.

Authorities of the municipality have agreed that the adequate management of waste will allow improving the living conditions of the community, reducing gastrointestinal diseases and minimizing negative impacts on the aquatic environment.

The implementation of the model project has generated a management of wastes' culture, both in the community as well as in the D.M.P.S.

With the new system adopted by the D.M.P.S. in order to develop and control the service, the City Council is ready to study a tariff for the service, in order to obtain incomes that are required for carrying out the replacement of equipment and increasing the coverage to other communities.

The adequate design and control of the service has shown to the municipality that this is an efficient mechanism through which the coverage of attention may be increased.

Authorities of the Municipality have understood the need of settling in a short term a kind of fee for the cleaning service. This fee will permit them to maintain the new service and to extend it to other communities.

The community is aware of the importance of the adequate management of wastes and is able to collaborate with activities carried out by the municipality in this subject.

18.4.2 Recommendations

The objectives formulated in the M/P of Solid Waste Management should be considered as part of the municipality development plans.

It is important to study in a technical way and to enforce on the short term a tariff for charging the service. A proper alternative is to charge on the first place commercial sectors and over generators and later to charge the community. In the later case, the cashing may be associated to the application of a subsidy directed exclusively to the lower income sector.

To approve and to apply in the short term a Regulation for the Rendering of the Public Service of Integral Management of Urban Solid Waste.

To purchase two trucks with compacting bunker and to improve the mechanical status of the current bunker trucks.

To improve the operation of the final disposal place. It is crucial that together with the improvement and increment of the coverage of the collection service, the final disposal place be improved. The current conditions of operation represent a serious risk to the environment and the implementation of the M/P. In this respect, it is recommended that the municipality destines in regular basis equipment for the accommodation of wastes in order to minimize the area contaminated with wastes and the generation of fires. The operation of the dumping site should be directly supervised by the D.M.P.S. who should establish an advancement program for the final disposal of waste.

Chapter 19

Establishment of Solid Waste Management System in Costa Maya

19 Establishment of Solid Waste Management System in Costa Maya

19.1 Background

In Mexico, the touristic industry is an important economic activity only surpassed by the oil sector. The state of Quintana Roo is one of the main touristic destinies in the country.

The visit of four million tourists to Quintana Roo generates an income of US 4,000 millions, which approximately represents 40% of the total national touristic income. This revenue is vital for the Mexican economy and as such, should be maintained.

In the decade of the 60s the area where Cancun is now located was practically uninhabited. It was in 1970 when the construction of Cancun started and in 1974 was enacted the creation of the Free and Sovereign State of Quintana Roo

Actually, Cancun has over 35,000 hotel rooms and its airport is only surpassed on traffic by the International Airport of Mexico City. Furthermore, it is annually receiving almost three million tourists.

The coastal strip known as Riviera Maya comprises from Puerto Morelos to Tulum and all along the coast are located Punta Bete, Playa del Carmen, Xcaret, Puerto Aventuras, Xpu-Há, Akumal and Xel-Ha. There are approximately 15,000 hotel rooms and the area receives more than 800,000 tourists annually.

Cancun and the Riviera Maya, are both generating simultaneously some economic growth in the state economy whilst at the same time are impacting the environment and natural resources. Such impact may potentially deteriorate resources and consequently make less attractive these important tourist destinations, just like has happened in other places in Mexico.

Costa Maya is located from Punta Herrero to Xcalak and touristic development is considered the way to achieve the economic growth on the south of Quintana Roo.

The Costa Maya development project pretends to promote low impact tourism and tourism of low density with an exclusive destiny. It will be specifically directed to small groups who will visit reserves, beaches, reefs, archeological places and hotels built in harmony with nature. In other words, the tourism development plan pretends to promote sustainable development

The Model Project is oriented to the development of a minimization culture regarding the integral management of solid waste. This is thought to be maintained and to progress altogether with the development of the touristic industry and future human settlements.

These initial steps will conduct to shared responsibility, prevention of the generation, valorization and to the integral management of solid waste foreseen in the new General Law for the Prevention and Integral Management of Waste (Federation's Official Magazine, October 08, 2003).

19.2 Summary

The table below summarizes purposes, outcomes, inputs and results of the Model Project.

Table 19-1: Outcomes of the Model Project Establishment of Solid Waste Management System in Costa Maya

Project Summary	Outcomes
Overall goal M/P is implemented	The strategies and measures proposed in the M/P for the establishment of Solid Waste Management System in Costa Maya are being achieved.
Project Purpose The creation of a minimization culture in the integral management of solid waste, to be maintained and strengthened according to the development of the touristic industry and future human settlements. The main purpose is to protect the aquatic environment.	The community of Mahahual is incorporating in the management of solid waste the practice of minimization. The formation of a minimization culture is assured through the approval of an institutional and organizational framework and the participation of the municipal authorities, residents and visitants, educational centers, hotels, restaurants and stores, harbour and the facilities for cruisers. Solid waste is disposed in a manual landfill. The municipality of Othon P. Blanco is incorporating in the revision of the Urban Development Program of Mahahual the recommendations contained in the M/P and it has started the procedures for obtaining funds from FONATUR for the construction of a new landfill in Costa Maya.
Outcomes A. Current system 1. Formation of the organizational structure. 2. Minimization of Solid Waste. 3. Improvement of final disposal 4. Sustainability in the service B. Future development 5. Protection of the aquatic environment	A. Current system 1.1 Creation and municipal acknowledgement of the Commission for the Management of Solid Waste in Mahahual. (CSWM) 1.2 Approval of the Community Regulation for the Collection, Management and Final Disposal of Solid Waste in Mahahual 1.3 The project of the Regulation for the Rendering of the Public Service of Integral Management of Urban Solid Waste has been given to the Municipal Town Council of Othon P. Blanco for its approval. 1.4 The municipality of Othon P. Blanco is incorporating in the revision of the Mahahual Urban Development Program, the recommendations contained in the M/P. 1.5 The municipality has decided to structure an administrative unit in charge of the development of Costa Maya. 2.1 In the main avenue were installed five stations of waste separation. 2.2 Two composters where donated to a group of restaurants in order to start a program of management of organic waste. The experience did not result positive due to the high content of humidity in the wastes. 2.3 In the Tele High school was constructed a composter in order to receive the waste of restaurants. The experience has been successful. Students plan to install a school orchard using all compost that has been produced. 2.4 Beaches are clean. Visitants make use of the infrastructure of separate discharge. 2.5 ECOCE Company has started its negotiations with the CSWM in order to collect all PET containers.

Project Summary	Outcomes
	3.1 A manual landfill has been constructed. The municipality will be in charge of the operation. 3.2 The municipality has started the procedures with FONATUR in order to obtain funds for the construction of a landfill that gives service to all Costa Maya. 3.3 The municipality has started to charge for the services of solid waste management to stores and to the enterprise which owns the cruisers' harbor (Puerto Costa Maya). A rate/fee structure is in preparation, which may assure the financial sustainability of the system. B. Future Development The generation of BOD coming from solid waste will tend to be moderated and manageable and consequently will be the impact over the quality of the aquifer and the aquatic environment. Urban growth will be regulated by the Urban Development Program where the recommendations of the Master Plan will be incorporated. The minimization and the correct application of the Regulation for the Rendering of the Pubic Service of Integral Management of Urban Solid Waste will contribute to the effective control of the generation of leachate.

Contributions

Personnel of the S/T

The work team was leaded by Ing. Victor Ojeda who was in charge of the design of the strategy, planning and conduction of the activities. Lic. Citlalli Suarez compiled and analyzed the information from several sources and conducted the opinion survey. Lic. Hiram Diaz directed the construction of the infrastructure and controlled the construction of the manual landfill. Ing. Ikuo Mori reviewed and approved the strategy.

Amigos de Sian Ka'an participated in the works of quantity and composition of solid waste; organization of the community; evaluation of the recycling and composting programs, program of public information and environmental education. Its participation has been very important in achieving the objectives of the project.

Personnel of the C/P

Ing. Héctor Morín has been the officer of the counterpart; reviewed and approved the strategy and plan of activities; he investigated the execution of the infrastructure works and the construction of the manual landfill. The biologist Luis Gonzalo Vidaña conducted the programs of environmental education in the community.

Personnel of the community:

The participation of the community leaded by the Commission for the Management of Solid Waste of Mahahual has made possible that in short time be achieved the objectives of the model project. It can be affirmed that the challenge of establishing a culture of minimization has been taken by the community with seriousness and responsibility.

Infrastructure and materials

The total amount donated by JICA was $250,000 pesos. Five stations of waste separation were constructed and several posters were hanged inviting people to dispose waste: in their place and separately.

A manual landfill was constructed with two trenches of 67.5 m3 each one and also tools and uniforms were delivered to the operators. Didactic material was delivered in educative centers in order to promote minimization.

19.3 Evaluation

a. Efficiency

The S/T called the representatives of diverse organizations in the community in order to introduce them the model project that was pretended to be developed in the community of Mahahual. Several meetings were carried out and the activities foreseen were adjusted to the comments of the participants. The budget of $250,000 pesos was donated by JICA.

It has been possible to assure the creation of an organizational structure at the community level through the creation of the Commission of Management of Solid Waste in Mahahual and the approval of the Community Regulation for the Collection, Management and Final Disposal. The municipality of Othon P Blanco will also have a specialized structure which will direct the urban development of Costa Maya and which necessarily will include the integral management of SW. These advances were achieved thanks to the participation of community and municipal members.

The process of a minimization culture has started with the separation of recyclable materials in the five stations constructed and with the composting of organic waste coming from restaurants. Students from the Tele High School are pioneers in the utilization of composting by starting shortly a school orchard. If this practice is universalized, then it would create a source of jobs and supply of aliments which characterizes organic agriculture.

Final Disposal has been improved through the construction of a manual landfill which has an initial capacity of 125 cubic meters; the discharge of SW to the landfill has reduced substantially.

The three government levels have asked the private sector to participate in the touristic development of Costa Maya with the purpose of strengthen the economic growth of the southern zone of the state. FONATUR, as governing organ at the federal level, is leading all these actions.

The funds provided by JICA have been used efficiently given the importance of the products achieved in the short term.

b. Effectiveness

The purpose of the project has been achieved partly because the practice of minimization started with huge interest of the participants. In the short term this practice will become in a culture that will be part of the community behavior on the protection of its natural resources and its sources of employment.

The results on the development of the model project have motivated FONATUR to finance the new landfill that will serve Costa Maya and which will incorporate two transfer stations. The construction of this landfill will require an important investment at the final stage, assuring in this way the protection of the aquatic environment through the control of leachate discharge (BOD) in the aquifer.

Concerning the development of a minimization culture and the integral management of solid waste, the strategy of the model project showed its effectiveness.

c. Impact

The model project has generated only positive impacts. Both the community and the authorities of the three government levels have agreed in that the implementation of the Master Plan is the alternative for the effective protection of the aquatic environment against the impact of solid waste. A culture of minimization is the base of this strategy given the geological and hydrological conditions of the Yucatan Peninsula.

d. Relevance

Minimization in the discharge of solid waste is associated to diverse aspects of economic and financial nature, social, cultural, environmental, technological and political: lower costs in the collection, transportation and final disposal of waste; reduction of the illness related to the pollution of the aquifer and the consumption of bottled water; protection of the coastal aquatic environment and preservation of the reef system; touristic promotion as a destine of sustainable development; generation of jobs and improvement of the life conditions in the southern zone of the state.

e. Sustainability

Through the General Law for the Prevention and Integral Management of Waste (Official Magazine of the Federation, October 08th, 2003), the areas of responsibility of the three government levels regarding the management of solid waste have been established.

SEMARNAT, SEDUMA and the municipalities have an area of responsibility and action in the management of solid waste in Costa Maya. In the organizational structure of each one of them there is an administrative unit associated to the management of solid waste.

However, the relation of coordination is still weak according to what is stipulated by law and which obliges to a coordinated action.

The implementation of the Master Plan may be a mechanism through which the activities of the organizations may be coordinated, by presenting objectives and specific goals to be achieved.

A system of information and coordination has been structured as a tool through the model project "Establishment of an Integral Waste Management Information System".

If the project "Regulation for the Rendering of the Public Service of Integral Management of Urban Solid Waste" is approved in the next municipal council, the regulatory and organizational framework will be stipulated and the sustainability of the integral management of solid waste in Costa Maya will be assured.

Additionally, the municipality of Othon P. Blanco has taken the commitment of structuring an administrative unit of urban development for Costa Maya, which will include the planning and control of the management of solid waste and will formulate a scheme of fair and equitable fees which permits the financial sustainability of the system.

The participation of the community in the regulation of the services is through the Commission for the Management of Solid Waste in Mahahual and through its "Community Regulation for the Collection, Management and Final Disposal of Solid Waste in Mahahual", both of recent creation and approval.

The sustainable development of Costa Maya should be the goal in order to maintain the touristic attractions which allow a permanent harmonic growth.

Costa Maya has places of unique beauty but with huge ecological fragility. It is crucial to establish, transmit and apply all regulations that protect these natural resources in order to avoid the repetition of negative and expensive experiences that have happened in other zones of the state.

The three government levels should coordinate their efforts within the ambit of their respective competences and assure the sustainability of the development of Costa Maya. By the same token, FONATUR will consider the financing of a new landfill under the base of the document "Executive Project for the Management and Final Disposal of Municipal Solid Waste in Costa Maya, Municipality of Othon P. Blanco", prepared by the College of Geologists of Mexico, A. C. (February 2002).

19.4 Conclusions and Recommendations

a. Conclusions

- The strategy and the measures proposed in the M/P are being executed.
- The promotion of the touristic development in Costa Maya is a fact; the competent authorities are inviting investors.

- The community of Mahahual is incorporating the practice of minimization in the management of their solid waste.
- The authorities of the three government levels have agreed in that the implementation of the Master Plan is the alternative for the effective protection of the aquatic environment against the impact of solid waste.
- The information and coordination among the three government levels is still weak.

b. Recommendations

- The implementation of the Master Plan must be considered as an objective of the public policies of the three government levels.
- Apply the regulations established in the "General Law for the Prevention and Integral Management of Urban Solid Waste".
- The municipal authorities should consider the approval of the project "Regulation for the Rendering of the Public Service of Integral Management of Urban Solid Waste".
- The municipality of Othon P. Blanco should incorporate the recommendations of the M/P in the revision of the Mahahual Urban Development Program" and structure an administrative unit which assumes the responsibility of the management of solid waste in Costa Maya.
- Officially recognize and support the Commission for the Management of Solid Waste in Mahahual and apply the "Community Regulation for the Collection, Management and Final Disposal of Solid Waste in Mahahual".
- Support the initiative of FONATUR for financing the new landfill and the transfer stations in Costa Maya.
- To require the private sector to participate in the activities of minimization of solid waste by taken as an example ECOCE.
- Structure and apply equitable and fair fees that permit to assist the cost of the rendering of the service of solid waste management.

Chapter 20

Environmental Education and Recycling Activities

20 Environmental Education and Recycling Activities

20.1 Background

There is a Law of Ecological Balance and Environmental Protection of the State of Quintana Roo, which includes several articles related to the solid waste management and recycling. A series of actions are listed below:

- To carry out actions toward waste reduction, reuse and recycling of domestic and non hazardous industrial waste.
- To prepare and propose programs for social participation, which contribute to delegate people responsibilities for conservation and improvement of the environment.
- To promote and spread informative material regarding environmental problems, the suitable method to mitigate them and solve them, as well as methods to taking advantage of the natural resources, using the different means of local media, promoting a new ecological culture in the citizens of the State.
- To promote, diffuse and coordinate programs of formal and non formal environmental education that are given in the State.

Regarding the above, there are many institutions which are working with environmental education programs. However, there is no coordination among them; therefore, the environmental education does not take the diffusion and practical dimensions focused to the problem of an appropriate solid waste and wastewater management. Also, recycling activities are not promoted at governments' level (state and municipal). This activity is mainly practiced informally by the private sector.

Under these circumstances, this Model Project aimed at providing an education program that can make children be acquainted with importance of resource conservation and recycling through harmonized coordination of different institutions.

20.2 Results

The table below summarizes purposes, outcomes, inputs and results of the Model Project.

Summary of the Project	Results
Global goal Environmental education and recycling activities are implemented.	1. The strategy and the measures proposed in the M/P for environmental education and recycling activities are on-going. 2. Increase of knowledge and interest on SWM aspects and recycling among students.
Purpose of the Project 1. The children that will be the main actors of the next generation take knowledge of the importance of the recycling and the conservation of resources. 2. The model project gives origin to the conservation of resources through recycling and protect the aquatic environment.	1. Activities in schools a. Workshops on SWM and wastewater for teachers were carried out in the Study Area. b. Following the workshops imparted to teachers, they carried out experimental classes in schools with students of higher grades. 2. other activities related to environmental education program
Outcomes A. Communication improvement for environmental education activities between related institutions within the state and municipality sphere. B. A recycling system focused to schools was established.	1. Formation of an Executing Unit integrated by SEDUMA, OPB and CAPA personnel, and the commitment of this Unit to follow the environmental education model project and the recycling activities. 2. The personnel of C/P (OPB, FCP, CAPA and SEDUMA) were trained in environmental education through work sessions and workshops. 3. Trained personnel of C/P in turn, trained elementary school teachers to carry out experimental classes with students of higher grades. 4. Implementation of experimental classes on environmental education in schools. 5. Implementation of recycling activities in elementary schools. 6. Participation of the private sector (recycling company) for paper recycling activities. 7. Commitment of the Executing Unit for follow-up of the model project of environmental education and recycling activities at state level.

Inputs

The working team for environmental education program was led by Mr. Masaharu Kina of JICA Study Team with the assistance of Maria Antonieta Bocanegra. The environmental education program and education materials (educational booklet on solid waste and wastewater management, booklet with compositions and illustrations by students, educational video, educational panels, poster and leaflets) were planned and designed entirely with the joint participation of the C/P Team integrated by Mr. Jose Mcliberty and its staff (SEDUMA), Mr. Gonzalo Vidana and its staff (OPB) and Mr. Jorge Jimenez and its staff (CAPA).

Amigos del Sian Ka'an (ONG) participated in the implementation of workshops and environmental education activities. The participation of Amigos del Sian Ka'an has been important in order to reach the objectives of the model project of environmental education.

JICA finances the production of the following education materials

1) Poster (1,000 units)
2) Education panels (10 units)
3) Educational booklet (1,000 copies)
4) Booklet with students works (1,000 copies)
5) Leaflets (1,000 units)
6) Education video 1 lot (30 copies)

All editorial materials and video used in environmental education activities (workshops, experimental classes and other related activities) were received with great acceptance by the recipient group.

It is necessary to mention that the educational video was transmitted by a state television channel (Channel 7 MAS) during several days in educational and children programs.

20.3 Evaluation

Follow-up and monitoring of environmental education activities were carried out by the C/P team of SEDUMA, CAPA and the municipality of Othon P. Blanco, during the period of March to June of 2004.

a. Efficiency

The participation of the C/P, the S/T and the school community in workshops has been the main contribution in the environmental education model project. This model project has been focused to facilitate and to outline some proposals which allow linking a community needs with a feasible project at short time (demonstration), and medium term (actions); what will allow to implement and to strengthen new strategies of the model project expansion. In that sense workshops have been developed with concrete proposals considering: a school activity of environmental conservation including educational aspects and environmental sanitation; a demonstrative activity related with solid waste management and wastewater; and an educational activity promoting the use of recyclable materials. This participation, in addition to the preparation of didactic and supporting materials (educational booklet, students' booklet, educational panels, poster, leaflets and educational video) carried out by the C/P and the S/T that were used to implement the environmental education activities, it was the key to achieve the expected effect.

On the other hand, the funds given by JICA were used efficiently by the importance of the achieved products and in short time.

b. Effectiveness

It can say that the purpose of the model project has been achieved successfully since it has begun with a great interest the environmental education model project and recycling activities.

It is expected that at the medium term to become a culture that would be part of the community for resources protection and preservation of the aquatic environment of the coastal area of Quintana Roo state.

The results of the workshop for teachers carried out by the C/P have motivated the school communities to carry out experimental classes related to solid waste management and wastewater and to implement recycling activities.

Regarding the waste minimization through solid waste management and recycling, the strategy of the M/P demonstrated its effectiveness.

c. Impact

It is still early to measure the impact of the model project at municipal/state level. However, the model project has generated very positive effects at institutional level and the schools where the training workshops and experimental classes were implemented.

d. Relevance

The recycling activities are associated to several aspects of economic, financial, social, cultural and environmental nature, smaller costs in waste collection, transport and final disposal, and consequently contributing to resources conservation and protection of the aquatic environment, tourist promotion, employment generation and improvement of the life in the coastal area of the State.

e. Sustainability

SEMARNAT, as SEDUMA, CAPA, the municipalities and the communities have an environmental responsibility and action to manage the solid waste and wastewater in the State. In every organization structure of related institutions has an administrative unit associated to the solid waste management. However, coordination among them is weak; therefore, the establishment of an executing unit was proposed to carry out the model project of environmental education and recycling activities.

The enforcement of this unit and the implementation of the M/P can be a mechanism to achieve the sustainability of the model project of environmental education and recycling activities.

The participation and cooperation of the community in recycling activities will be extremely important for the achievement of the objectives and the sustainability of the project.

f. Evaluation of capacity building for environmental education and recycling activities (self-evaluation)

The results of self-evaluation made by the C/P team after the implementation of the model project of environmental education and recycling activities are shown below:

Evaluation :	Very good	4	Good	3	Average	2	Poor	1

No.	Item	OPB	CAPA	SEDUMA
1	Knowledge and methods			
a.	Understanding of the objective of environmental education	4	4	4
b.	Understanding of tecniques and methodologies used for environmental education training (making of education materials and workshops)	4	4	4
c.	Understanding of techniques and methodologies learned	4	4	4
d.	Level of effectiveness of the implemented techniques and methodologies	3	4	4
2	Technique and Action			
a.	It can implement training workshops on environmental education in schools and communities.	3	4	4
b.	It carries out the follow up of paper recycling in schools.	2	3	4
c.	It carries out environmental education and/or recycling activities in other areas.	3	3	3
d.	Knowledge of effective methods and techniques to elaborate manuals and information and supporting materials for environmental education programs.	3	4	4
e.	The materials used in the workshops were appropriate.	4	4	4
3	Responsibility and attitude (of the institutions)			
a.	It carries out periodic visits to schools where the recycling program is implemented.	3	4	3
b.	It carries out meetings and activities to promote recycling program in other municipality schools.	3	3	2
c.	It uses methods and comprehensible educational instruments for children and residents of the community.	3	4	3
d.	It supports the teachers in experimental classes	3	4	3
3	The private sector (participant companies in recycling program)			
a.	The company picks up the paper gathered in the schools according the agreement signed between the parts (school-company).	2	3	3
b.	Generally, the Company is fulfilling the agreement with the schools.	2	3	2
4	Schools where paper recycling program are carried out			
a.	The teachers, authorities and students have understood the necessity of the environmental education and recycling activities.	3	4	4
b.	The enthusiasm of the recycling program is increasing.	4	3	3
c.	Diffusion of the strategies proposed in the workshops.	4	4	4
d.	The school carries out the paper recycling program.	2	3	2
e.	Follow up of recycling activities is carried out by the involved institutions.	2	3	3
f.	There is parent participation.	2	3	2
	Points (total 84 points)	62	75	69
	Points (percentage)	74	89	82

Of a total of 84 points (100%) all those interviewed overcame 70% of the capacity. With regard to the environmental education and recycling activities implemented it can conclude that:

- The recycling program is contributing for the preservation of the aquatic environment in the coastal area of Quintana Roo State.

- The C/P team follow the activities of environmental education through training workshops, experimental classes and paper recycling activities in elementary schools.
- Formation of multiplier agents has settled down to develop recycling program.
- It has been possible to diffuse what they learned in environmental education workshops to other groups in schools and in communities.
- It has been carried out other activities related to environmental education program in the communities.
- The impact of environmental education and recycling activities in the community has been very positive.

20.4 Conclusions and Recommendations

a. Conclusions

- The strategy and proposal measures in the P/M are on going.
- With the implementation of the Model Project of Environmental Education and Recycling Activities, the C/P formed a Working Team where the institutions can share their experiences and to enrich the actions and impact of the project in the State.
- The working team (Executing Unit of Environmental Education) has carried out the short term program of environmental education activities (training workshops for teachers, experimental classes and other activities related) successfully.
- The school community is incorporating the waste minimization practices through paper recycling activities.
- Coordination among the private companies, schools and the institutions is still weak.

b. Recommendations

- To conform and consolidate in permanent form the Executing Unit being SEDUMA the coordinating organism.
- To implement a monitoring system for environmental education program and recycling activities.
- To incorporate in a permanent way the Ministry of Education participation in the Executing Unit.
- To promote community and parents participation in recycling activities.

- To invite the private sector to participate in solid waste minimization activities.
- To foment and institutionalize recycling activities at state level.
- To monitor the recycling activities between the private companies and schools.
- To obtain incentives and finances to reinforce the environmental education activities with the participation and support of the private sector.

Part V

Conclusion and Recommendations

Chapter 21

Conclusion and Recommendations

21 Conclusion and Recommendations

21.1 Conclusion

21.1.1 Conservation of Coastal Aquatic Environment

a. What is the Coastal Aquatic Environment

The karst topography of Yucatan Peninsula, which is permeable and soluble, formulates unique coastal aquatic environment being composed of reefs, lagoons, mangrove forests, caves and cenotes. There is no river on surface in the Study Area except Rio Hondo that runs on the border between Mexico and Belize. Rain percolates and streams under the ground, then, flows out to the coastal area. Namely, the groundwater directly connects with the coastal aquatic environment and nurtures this rich environment. Therefore, it is reasonable to comprehend the coastal aquatic environment including the groundwater in the Study Area.

b. Value of the Coastal Aquatic Environment

In the State of Quintana Roo, the above mentioned coastal aquatic environment stretches from Cancun to Costa Maya. The coastal aquatic environment is important as a tourism resource and habitat of various creatures. In addition, the groundwater is indispensable for human living as the unique water supply resource.

The tourism industry is not only important for the State of Quintana Roo, but also for the Country of Mexico. Foreign currency earning by the tourism industry ranks third following one by oil and by workers in foreign countries. In 2000, the tourism industry earned 8,300 million dollars. One third of the amount came from the State of Quintana Roo. In addition, the tourism creates job opportunities, then, it is also important for the regional economy.

The unique coastal aquatic environment provides habitats for various animals and plants. About 670 species of animals and 1,500 species of plants inhabit the State including endangered species such as manatees, jaguars and green turtles.

c. Threats to the Coastal Aquatic Environment

As mentioned above, the coastal aquatic environment faces various threats caused by the rapid urbanization being brought along with the tourism development. The threats can be divided into direct environmental disruption, such as housing land development, road construction, and construction of hotels, and indirect environmental disruption, such as over exploitation of groundwater for water supply and groundwater contamination caused by inappropriate disposal of wastewater and solid waste.

Regarding the direct environmental disruption, POET (Programa de Ordenamiento Ecologico Territorial) that is a zoning ordinance works as an effective tool. In the Study Area, three areas of Costa Maya, Sian Ka'an Biosphere and Corridor Cancun - Tulum are regulated by the POETs. In addition, a new POET is under preparation targeting a Bacalar area.

Meanwhile, measures by the state and the municipalities have not caught up with problems of water supply, wastewater treatment and solid waste disposal brought by the rapid increase of population and tourists. It is feared that the indirect environmental disruption is rapidly and seriously developed.

The objective of the Study was to formulate the Environmental Sanitation Management Master Plan aiming at preserving the coastal aquatic environment along the coast of Quintana Roo State in Yucatan Peninsula, which was to cope with the indirect environmental disruption.

21.1.2 Preservation of Groundwater

a. Threats to the Groundwater

The groundwater nurtures the coastal aquatic environment which is important as a resource for tourism and a habitat for various animals and plants, and is a unique source for drinking water in Yucatan Peninsula.

The fresh water layer in the peninsula is thin due to intrusion of the sea water. In areas close to the coastal line, groundwater becomes saline water under 5 or 10 m from the surface. Most of extraction wells for water supply are located in the interior about 20 or 30 km from the coastal line where the fresh water is developed to the depth of around 50 m or more, however, over exploitation may cause local salinization.

It is considered that the most serious threat to the groundwater is domestic wastewater from houses and hotels. Sewerage coverage rates in the Study Area are very low such as 16% in Othon P Blanco, 1% in Felipe C Puerto and 5% in Solidaridad. Even in areas covered with the sewerage system, residents hesitate to connect their in-house drainages to the public sewer due to economical reasons. Furthermore, because of absence of rivers on the surface, treated wastewater from sewage plants is discharged in the saline water layer under the ground, then, it contaminates the groundwater.

Waste collection works in urban communities in Othon P Blanco and Solidaridad have been relatively well done. However, disposal of waste is inadequate, which causes a large amount of leachate and contaminates the groundwater.

The service industry focusing on the tourism is the most important industry in the Study Area. The manufacturing industry has not yet been developed and the agriculture is not rampant. Therefore, it is assumed that domestic wastewater and solid waste from houses and the service industry, namely from residents and tourists, are principal pollution sources to the groundwater. The Study estimated that 60 % of the pollution load accounts for the domestic wastewater and 40 % for solid waste.

b. What would happen in the Future?

Rapid increase of population and tourists is forecast in the Study Area. Forecast population in 2015 is 893,000 which is twofold of the estimated population of 435,000 in 2003. Meanwhile, 1,757,000 tourists in 2003 is estimated to become 3,156,000 in 2015.

If no new measures are taken in the sectors of wastewater and solid waste, it is predicted that the groundwater will be contaminated to 4.9 mg/litter of BOD due to the pollution load originated in the sectors. This level of contamination is categorized as Class C in the environmental standard for river water in Japan, which means the groundwater will not be suitable as a source for drinking water. Furthermore, that will deteriorate the coastal aquatic environment such as cenotes, caves and reefs.

Such environmental deterioration will bring about loss of attraction as a tourist resort, loss of biodiversity and health hazard. It is estimated that foreign currency earnings by tourism until 2015 will be 10,529 million pesos below the original forecast.

It is concluded that the pollution load originated in wastewater and solid waste will contaminate the groundwater; that leads to deterioration of the coastal aquatic environment; consequently, a sustainable development of the Study Area will be hampered.

21.1.3 The Master Plan

a. Basic Concept

The proposed Master Plan sets “To contribute to regional sustainable development of Yucatan Peninsula” as the guiding principle, “To preserve the groundwater and the coastal aquatic environment in the southern Quintana Roo State through the adequate management of wastewater and solid waste” as the principal objective, and “To clarify respective responsibilities of the public sector, the private sector, the residents and the tourists, and to encourage their appropriate participation in the Environmental Sanitation Management” as the basic approach.

As the target values of the Master Plan, it is proposed that BOD discharge amount originated in wastewater and solid waste is to be less than 5,200 ton/year by 2015, aiming at controlling

BOD concentration of the groundwater 1.0 mg/litter and below; less than 3,100 ton/year from wastewater, and less than 2,100 ton/year from solid waste.

b. The Wastewater Management Master Plan

In order to achieve the target mentioned above, the Wastewater Management Master Plan proposes various treatment levels taking into account the characteristic of population distribution in the Study Area; higher treatment level (more reduction of pollution load) for larger population and lower treatment level for smaller population. Reduced pollution load amount per cost is larger in a greater facility. Thus, the Master Plan proposes to prioritize projects in larger communities taking into account cost-effectiveness. The responsible institution is CAPA (Commission of Potable Water and Sewerage).

Total cost of the Master Plan is 3,300 million pesos till 2015. Results of the financial analysis say that the current tariff can basically cover the total cost in case of considering the Study Area as a unit, however, the tariff can not cover the cost in Othon P Blanco and Felipe C Puerto in case of considering the municipalities individually.

c. The Solid Waste Management Master Plan

The Solid Waste Management Master Plan targets urban communities which will have population of more than 25,000 in 2015 taking into consideration relation between community sizes and demands for solid waste service. It also proposes higher waste collection rates and more sophisticated waste disposal manners for lager communities. In addition, waste minimization is proposed, as it leads to reduction of pollution load and conservation of resources. Responsible authorities are the municipal governments. And, SEDUMA will guide and support them.

Total cost of the Master Plan is 1,178 million pesos by year 2015. However, incremental cost is only 441 million pesos as the solid waste service is currently provided. The financial analysis says that in order to cover the total cost of 1,178 million pesos, it is necessary to charge residents from 40 to 50 pesos/month/house and business entities from 150 to 200 pesos/month/entity. Then, financial self-sufficiency can be achieved.

d. Benefits

Expected benefits, which the Master Plan will bring about, are 1) keeping of attraction to tourists, 2) preservation of biodiversity and 3) protection of the water source for drinking water. Quantitative economic evaluation was carried out targeting the first benefit. In results, EIRR (Economic Internal Rate of Return) was 39.0%, NPV (Net Present Value) was 2,545

million pesos and B/C (Benefit – Cost Ratio) was 2.06. Then, It is concluded that the Master Plan is economically feasible.

21.1.4 Model Projects

Investigation on hydrogeological conditions and some measures listed in the Master Plan were carried out as Model Projects.

Urban Type Wastewater Treatment carried out at Playa del Carmen in Solidaridad clarified that the current manner of treated wastewater injection is not appropriate in view of the hydrogeological conditions of the site and there is a room for improvement. In addition, ammonia was found in the groundwater. It tells that the groundwater was artificially contaminated.

Residents are responsible for connection of in-house drainage to the public sewer. Financial burden for the connection and lack of knowledge about environmental conservation discouraged the residents from doing so. Then, even though CAPA constructed the public sewers, actual sewerage coverage was not increased. To cope with this problem, Village Type Wastewater Treatment established a fund to ease the financial burden and carried out explanations to residents along with environmental education. In results, the connection was promoted.

Establishment of an Integral Solid Waste Management Information System formulate a framework where SEDUMA and the municipalities exchange information of Solid Waste Management; the former is an institution of the state government and the latter are responsible for provision of solid waste service. The system is also to respond to a requirement of a new federal law, “General Law for the Preservation and Management of Waste.” In regard to this Model Project, it is proposed to establish an Executive Unit in SEDUMA for promoting and supervising implementation of the Master Plan and to enact a new municipal ordinance of Solid Waste Management based on the Master Plan.

Capacity Building of Executing Agency in Othon P Blanco aimed at establishing a manner of controlling solid waste service cost. This Model Project was carried out in collaboration with other Model Projects; Improvement of the Existing Disposal Site and Collection Improvement. Namely, technical data obtained from these Model Projects were combined with cost data, then, results of analysis of the combined data sent back for improvement of the disposal site operation and the collection works. Accordingly, the Model Project is to strengthen a core capability of the Integral Solid Waste Management. Information of cost was dispersed over several sections of the municipal government. Then, it was difficult to gather information at the beginning. However, communication channels among the sections were

established and awareness of improvement among the municipal personnel was boosted through the Model Project.

Through Improvement of the Existing Disposal Site in Othon P Blanco, dispersed waste over the disposal site was gathered in a certain area, compacted and covered with soil, which improved sanitary conditions; and an access road was constructed which significantly improved workability of the site. In addition, waste amount brought in the site was known due to installation of a weighbridge. The information of waste amount is one of the most important information in Solid Waste Management. Average disposal waste amount during the Model Project was 160 ton/day.

Collection Service Improvement was carried out in Othon P Blanco and Felipe C Puerto. Through the Model Project, a manner for planning collection routes, recording operation data and evaluating the data was established. In result, reduction of operation time of collection vehicles and increase of collected waste amount per crew were confirmed in Othon P Blanco. Those data tell possibility of cost reduction. In Felipe C Puerto, the Model Project increased collection coverage up to 80% which had been 50 % before the Model Project.

In the Model Project of Establishment of Solid Waste Management System in Costa Maya, several stations for separate collection were installed aiming at waste minimization; the stations were managed by a newly established committee on Solid Waste Management in a local community; and negotiation with traders regarding collected PET bottles and cans got started. Namely, a new Solid Waste Management System has begun to work.

Environmental Education and Recycling Activities prepared education materials such as a video and texts, established a manner of environmental education using the materials, and realized a paper recycling activity. These activities are carried out and expanded by the Mexican counterpart themselves.

21.2 Recommendations

21.2.1 Recommendations for implementation of the Master Plan

a. The Wastewater Management Master Plan

1. Improvement of Sewerage Coverage

- It shall be prioritized to develop sewerage system in urban communities, as that is cost effective in view of reducing pollution load and those communities generate a large amount of pollution load.
- The manual and the experiences acquired through the Model Project of Village Type Wastewater Management shall be utilized for construction and operation of sewerage system in small communities in the future.
- CAPA shall be after required investment cost for development of sewerage system in coordination with CNA.

2. Promotion of In-house Drainage Connection

- CAPA shall formulate a project team for promoting the in-house drainage connection. The team shall be composed of personnel from various sections such as planning, construction, operation and maintenance, and community relations.
- The promotion shall be conducted not only in areas where sewerage system exists, but also in areas where construction of sewerage system is planned. The promotion shall be carried out beforehand, e.g., before or at an early stage of construction works.
- In order to ease financial burden of residents, the fund established in the Model Project of Village Type Wastewater Treatment shall be expanded and further utilized.
- In order to raise residents' awareness on environmental conservation, explanations to residents shall combine environmental education.

3. Income Improvement and Cost Reduction

- The tariff of sewerage service, which is currently set as 20% of the water supply charge, shall be raised according to expansion of the sewerage service.
- Installment of micrometers shall be promoted and fee collection rate shall be improved.
- Indirect cost that currently occupies about 50% of the total cost shall be reduced.

b. The Solid Waste Management Master Plan

1. Improvement of waste collection coverage

- Improvement of collection works shall be continued based on the manuals prepared and the experiences acquired through the Model Project of Collection Service Improvement.
- Capacity reserved in the improvement shall be utilized for expansion of collection coverage.

2. Implementation of Proper Waste Disposal

- The existing disposal sites shall be improved consulting with the manual and the experiences acquired through the Model Project of Improvement of the Existing Disposal Site in Othon P Blanco.
- The current disposal manner shall be moved to sanitary landfill in Chetumal, Riviera Maya and Costa Maya according to schedule set in the Master Plan.
- Othon P Blanco Municipality shall be after required investment cost for construction of a sanitary landfill in Costa Maya in coordination with FONATUR.

3. Promotion of Waste Minimization

- The Model Project of Environmental Education and Recycling Activities shall be continued and expanded in coordination with the Ministry of Education and other institutions concerned.
- Paper recycling that was launched in the Model Project shall be expanded.
- Recycling of PET shall be promoted in coordination with ECOSE.
- Pruning waste composting shall be started out in the near future.

4. Actions towards Financial Self-sufficiency

- Fee collection of solid waste service shall be considered and implemented as soon as possible.
- A system to charge tourists for solid waste service shall be considered as soon as possible.

5. Strengthening of Institutional System

- Executive Unit that is to be in charge of guidance and support of Solid Waste Management shall be established in SEDUMA.
- The municipalities shall consider the proposed ordinance regarding Solid Waste Management.

21.2.2 Recommendations for Groundwater Preservation

1. Establishment of a Groundwater Monitoring System

- CNA shall establish a monitoring system that is capable to comprehend groundwater status quantitatively.
- Monitoring results shall be utilized for proper implementation of the Master Plan, e.g., if a monitoring result says that contamination of the groundwater is serious in a certain area, a recommendation of prioritizing construction of sewerage in the area can be induced.

2. Improvement and strengthening of Institutional System

- In order to make it possible that evaluation of monitoring results leads to necessary actions to protect the groundwater, the current institutional system shall be improved and strengthened, e.g., if quality of the groundwater is regulated quantitatively, results of monitoring can be evaluated according to the regulation and next actions can be taken immediately such as further studies or guidance.
- CNA shall begin to establish regulations on the injection well considering the results of the Model Project of Urban Type Wastewater Management.

21.2.3 Recommendations for Conservation of the Coastal Aquatic Environment

1. Water Quality Monitoring in Nearshore Waters

- Relation between quality of the groundwater and of the seawater shall be studied in coordination with monitoring conducted by the Navy in nearshore waters.
- The Navy's monitoring works shall be diagnosed and evaluated. If necessary, measures shall be taken for improvement of the monitoring system.

2. Promotion of Cooperation with Projects and/or Institutions Concerned

- Information shall be interchanged among related projects such as Mesoamerican Coastal Reef Conservation, and possible coordination shall be after.
- Information shall be interchanged among institutions dealing with environmental conservation such as University of Quintana Roo, ITCH (Instituto Tecnologico de Chetumal) and ECOSUR (El Colegio de la Frontera Sur).

In conclusion, the Study Team would like to appreciate organizations and individuals in both Mexico and Japan having participated in or cooperated with this Study. We expect that what we have done together will lead to a sustainable development of the Study Area, the State of Quintana Roo and the Peninsula of Yucatan.